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AIR FORCE RESEARCH REVIEW

Number 1 July-August 1970

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Air Force Systems Command

AIR FORCE RESEARCH REVIEW

Number 1 **July - August 1970**

FOREWORD

This first issue of the AIR FORCE RESEARCH REVIEW is the successor of the OAR RESEARCH REVIEW. The change in title reflects the merger of the Office of Aerospace Research into the Air Force Systems Command on July 1, 1970. The merger was effected in order to make a single agency responsible for all Air Force R&D from the time an idea is born in the mind of an Air Force or contract scientist until a scientific improvement has been made or a "new generation" piece of hardware has been developed.

The AIR FORCE RESEARCH REVIEW is published bimonthly by the Technical Information Division (DLLT), Air Force Systems Command, Andrews AFB, Washington, D.C. 20331. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities.

ETHEL GAMER, Editor

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AFSCRP 80-2

COMMENTS TO THE EDITOR

To stimulate a dialogue between the readers and our scientists, your comments, as indicated in the space below, are welcome on any article appearing in this issue. See also the note on the title page of the Readers Interchange.

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SOPHISTICATED RADAR DISPLAY

FOR UNIQUE AIRBORNE RADAR

Microwave Physics Laboratory, AFCRL

A highly sophisticated radar display will be mated to AFCRL's unique airborne Synthetic Aperture Dual Frequency Radar (SADFRAD) within the next few months when the entire system will be tested for the first time. The SADFRAD uses a dual harmonic phase signature technique which operates at two frequencies in the HF and low VHF regions. The synthetic aperture radar processes the incoming data on a real-time basis and converts the signal to digital form. The digital outputs of the synthetic aperture processor provide both target amplitude data and phase signature data at both frequencies.

The display of these data in a form meaningful to the operator demanded a new approach to radar imagery display design. One problem facing the designers was the relatively slow data rate of the radar processor, a rate too slow to produce a freshly updated picture on each frame of the TV-like line-scan display as the aircraft moves along its flight path. To present a continuous radar strip map on the display (rather than a succession of static pictures) required further digital processing in the display console equipment. Such equipment has been built for AFCRL under contract with General Electric.

This highly sophisticated display console provides the operator with three TV monitors—three windows on the moving terrain below. Each window shows the same scene under different processing parameters. Two of the views are in black and white; the third is in color.

The console equipment accumulates the processed radar data and reads continuously through all stored data at the standard television rate of 30 frames a second. The data are stored in a digital core memory system that is large enough to display 12,000 range/azimuth cells at one time. Newly processed data from the synthetic aperture radar enters the display at the top of the screen. Previously stored data are shifted downward, line by line. The oldest stored data drop off the lower edge of the picture and are discarded. In this way, a continuously moving view of the terrain is simulated.

For each of the 12,000 range/azimuth cells, the radar processor provides three multi-bit binary numbers. Two of the binary numbers are associated with the black and white displays; the third, with the color display. The color display is used for easy discrimination among various targets, highlighting similarities and differences for easier monitoring and recognition. The two black and white displays show the same area at different frequencies, amplitudes, and contrast levels. The signals going from the radar to each display can be combined by the operator on a single monitor when target features must be brought out that otherwise might not be discernible on the individual scopes.

One interesting feature of the console equipment is a "hold" button. Depressing this button enables the observer to stop the loading of a new line of input data and freezes the picture, much like a TV sports replay. He can then examine the picture in detail or photograph it for future study. Although the console equipment was developed for a special AFCRL radar system, the basic design may be modified to fit other applications.

Contact: Major Joseph J. Centofanti
Telephone - Extension 3716

Major Joseph J. Centofanti has been an electronics engineer at the Radiation and Reflection Branch of AFCRL's Microwave Physics Laboratory for the past two years. At present he is working on antenna and radar design.

He received a B.E.E. in 1957 from Manhattan College and an M.SE.E from the University of Colorado. He is a member of the IEEE.

Mr. Philipp Blacksmith, Jr., is Chief of the Radiation and Reflection Branch of the Microwave Physics Laboratory at AFCRL where he is primarily concerned with basic antenna research involving electrically and mechanically scanned fixed antennas. He is also the Project Officer for the Design and Construction of the Arecibo Ionospheric Observatory at Aercibo, Puerto Rico. He has been with AFCRL since March 1954.

Mr. Blacksmith received his B.S. in Physics from Carnegie Institute of Technology and his M.S. in Electrical Engineering from AFIT. He has published several articles.

COUPLING MECHANISMS IN COMBUSTION INSTABILITY

Professor T. Y. Toong, Massachusetts Institute of Technology

Despite intensive research and development effort during the past two decades, problems related to basic mechanisms of instability in chemically reacting media (such as combustion instability, detonation wave structure, turbulence spectra in reacting flows) remain poorly understood. Supported mainly by AFOSR, Professor T. Y. Toong of M.I.T. has been studying coupling mechanisms which would lead to instability in a reacting system. This report briefly reviews his past work and summarizes his current research.

Many mechanisms of combustion instability proposed to date are based on Rayleigh's criterion (1,2) which suggests that acoustic waves can be amplified if the proper phase relationship exists between the oscillating energy source and the acoustic density. Through linearization of the governing equations, no consideration has been given to the possible role of flows in the mechanism of energy transport to various oscillation modes. Such nonlinear coupling, however, has been observed in his early studies of flame instability in laminar boundary layers (3, 4, 5). One such study concerns oscillations of a pre-mixed flame in a forced-convective boundary layer of a combustible mixture flowing over a heated surface. Another study deals with oscillations of a diffusion flame around a simulated fuel droplet in a natural-convective boundary layer. In both cases, the experimental results indicate strongly that the onset of these self-sustained flame oscillations is due to instability of traveling Tollmien-Schlichting waves—the same mechanism which leads to the onset of transition from laminar to turbulent flows.

In a later study (5), experiments demonstrate that strong interactions between acoustic and flame oscillations can exist through flow oscillations and that these interactions are due to energy transport between various oscillation modes through both linear and nonlinear couplings. Furthermore, the intensity of these interactions is found to depend on the magnitude of flow velocity.

The exact role of flow in triggering instability has also been examined from a fundamental viewpoint. In two papers (6,7), theoretical results are presented showing detailed flow interactions which arise essentially from the nonlinear inertia terms in the governing Navier-Stokes equations. It is demonstrated, for example, that coupling exists between traveling acoustic waves and non-homogeneous flow fields and results in either amplification or attenuation of the waves, depending on gradients of velocity, density, and entropy in the flow and wave propagation direction. Some of these results have been verified in experiments.

Another important coupling which would lead to instability in reacting systems occurs between chemical kinetics and gas dynamics. This coupling is observed in a study of supersonic combustion for possible future application in hypersonic flight vehicle propulsion. When spheres or bodies of other blunt shapes are fired at high speeds into reactive gaseous media in a ballistic range, various flow regimes can be identified downstream of the bow shock. In one regime, the flow is steady and chemical reaction is confined to a laminar front between the bow shock and the body. In other regimes, two types of unsteady flows are observed: one with highly regular periodic oscillations and the other with rather large-scale "turbulent" structure. (Figure 1 shows two typical schlieren pictures.) Both theory and experiments indicate that this instability is

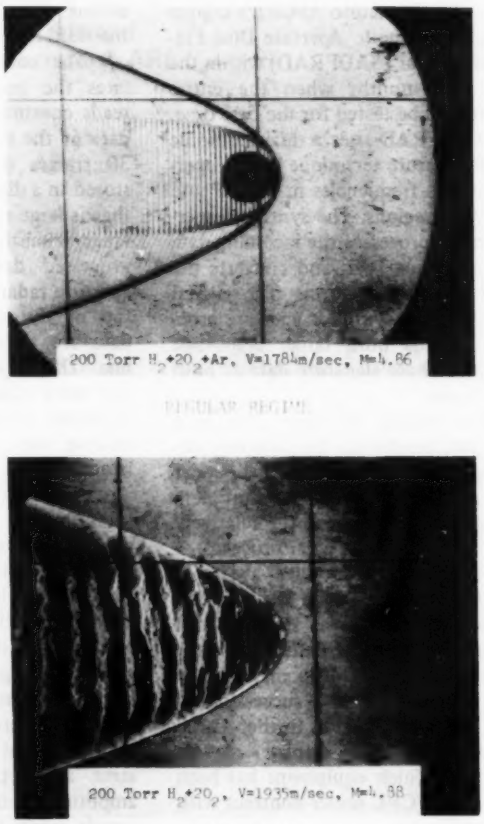

Figure 1. Schlieren picture showing two types of unsteady flow around a 12.7 mm sphere.

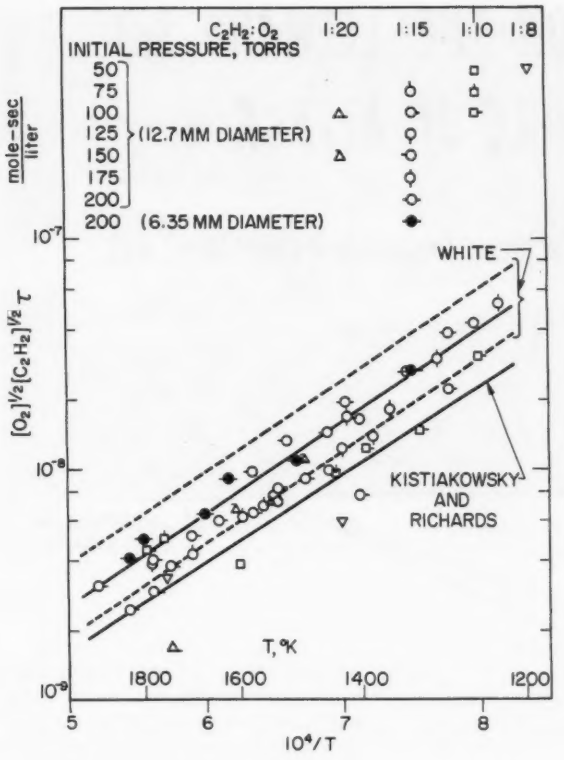

FIGURE 2

triggered by disturbances occurring in an induction zone in the stagnation region behind the bow shock as a consequence of sensitivity of induction time to temperature changes.

According to the postulated mechanism based on a wave-interaction model, compression waves or shocks are generated by formation of a new reaction front which results from reduced induction time behind a bow shock and which has been strengthened through interactions with the compression waves generated in a previous cycle. Detailed examination of characteristic flow features in the two unstable regimes shows that the same wave-interaction model can explain the instability in both cases.

The flow features examined include shock-detachment distance, amplitude of corrugations in the boundary between reacted and unreacted gas, degree of completion of chemical reaction, distortion of bow shock, and predominant period of instability. In all of these features, the magnitudes are larger in the turbulent regime. Such quantitative differences can all be accounted for by postulating that the compression waves interacting with the bow shock are stronger in the turbulent regime.

The same wave-interaction model can also explain the fact that the compression waves are stronger in the turbulent regime. In the periodic regime, it is found that these compression waves can be overtaken (and thus weakened before they interact with the bow shock) by rarefaction waves which are generated when a reaction front formed in a previous cycle is extinguished. In the turbulent regime, however, these compression waves can interact with the bow shock before being weakened by the rarefaction waves. This conclusion seems consistent with the experimental observations that the turbulent regime is more likely to occur at higher body speeds, higher initial mixture pressures, and less diluted reactive mixtures.

The experiments have also identified other characteristics like pressure and entropy waves which should be present in the flow field according to the wave-interaction mechanism. A quantitative verification of the postulated mechanism is shown in figure 2. In this figure induction time computed from the observed period of instability in the regular periodic regime for $C_2H_2 - O_2$ mixtures on the basis of the wave-interaction model is compared with that measured by Kistiakowsky and Richards (8) and White (9) in shock tubes. The results cover different values of sphere diameter and speed as well as initial pressure and composition of the acetylene-oxygen mixture. The agreement is satisfactory, especially in view of the scatter observed in each investigator's results and the difference between two independent studies carried out in shock tubes.

Although results obtained so far in Professor Toong's current research program indicate that the wave-interaction model is consistent in explaining the presence of various flow features in the different unstable regimes, still not clear are the detailed mechanisms by which instabilities are triggered in the first place and their subsequent development to the final stage as characterized by the two unstable regimes. Transient studies are in progress to unravel such mechanisms.

It is now understood that chemically reacting flows can become unstable, not only due to a linear mechanism as suggested by the Rayleigh criterion, but also due to nonlinear mechanisms resulting from flow-acoustic and flow-kinetic interactions. Hopefully, engineering solutions to either control or eliminate unstable combustion (in rocket engines, for example) can eventually be achieved through a thorough understanding of the basic instability mechanisms involved.

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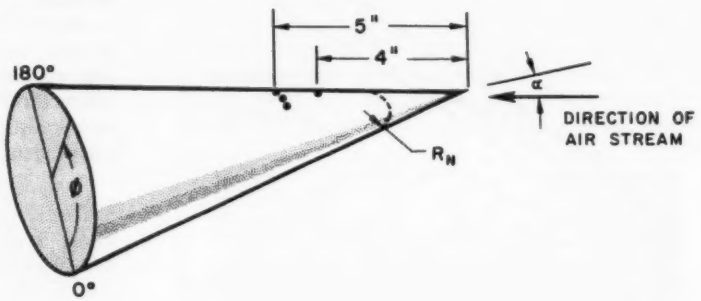
AERODYNAMIC HEATING ON THE LEEWARD SIDE OF A CONE AT ANGLE OF ATTACK

Kenneth F. Stetson, Fluid Dynamics Facilities Research Laboratory, ARL

In the past when engineers considered the leeward (sheltered) side of a body flying at moderate-to-large angles of attack, they usually made the assumption that the pressures and heating were low enough to be neglected. Recent experiments have indicated that such assumptions should not be made at hypersonic velocities. Although aerodynamic heating in regions of hypersonic separated flow does not appear to be large enough to produce catastrophic effects, it still must be considered and taken into account.

To obtain some preliminary data on the magnitude of aerodynamic heating on the leeward side of a body at angle of attack, experiments were performed in a shock tunnel. A 15-degree half angle cone was tested at Mach number 13.5. Figure 1 shows a sketch of the cone configuration and identifies the pertinent symbols. Figure 2 is an example of the heat transfer rates obtained. The heat transfer rate, q, on the leeward meridian at various angles of attack is compared with the heat transfer rate at zero angle of attack, $q_{(a = o)}$. Separation on a sharp cone at angle of attack is a gradual process; it is not possible to identify the precise angle at which separation occurs by referring only to heat transfer rates and pressure data.

From other data, in particular surface oil flow patterns (An example of surface oil flow patterns is shown in figure 3 which is a photograph of a model tested in the ARL 20-inch hypersonic wind tunnel.), it had been found that separation on a sharp cone typically occurred at an angle of attack from 80 to 100 percent of the cone half angle.



• LOCATION OF HEAT TRANSFER GAGES
Ø MERIDIAN ANGLE (180° IS THE LEEWARD MERIDIAN)
α ANGLE OF ATTACK
R_N NOSE RADIUS FOR BLUNT CONFIGURATION

Figure 1. Sketch of test configuration.

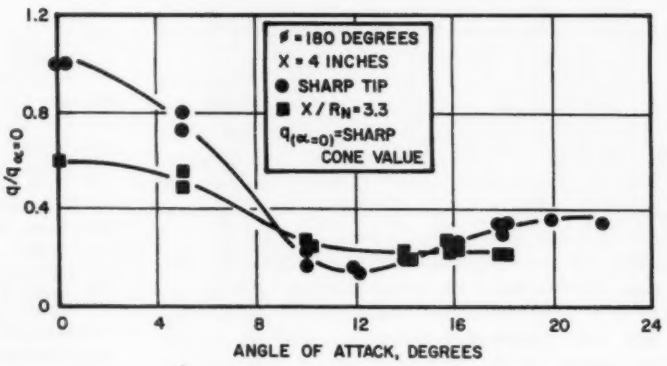


Figure 2. An example of heat transfer rate variations with angle of attack.

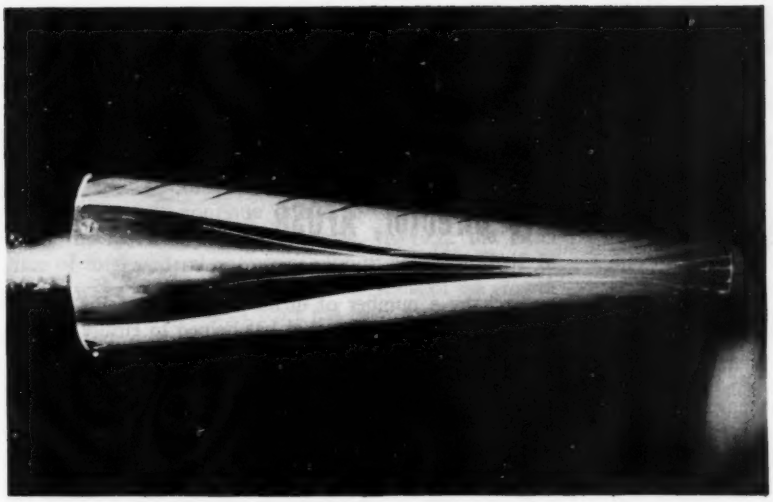


Figure 3. Photograph showing the surface oil flow patterns in the leeward region of a 5.6 degree half angle cone at 10 degrees angle of attack and a Mach number of 14.2.

It can be seen from figure 2 that, using a sharp nose tip, as the angle of attack proceeded through the range where boundary-layer separation would be expected (angles between 12 and 15 degrees), the heat transfer rate went through a minimum and then increased. At larger angles of attack, the heat transfer rate increased to nearly 40 percent of its value at that location at zero angle of attack. Figure 2 also shows an example of the corresponding heat transfer rates when the sharp nose tip was replaced with a blunt nose, with a nose radius equal to 0.84 inch.

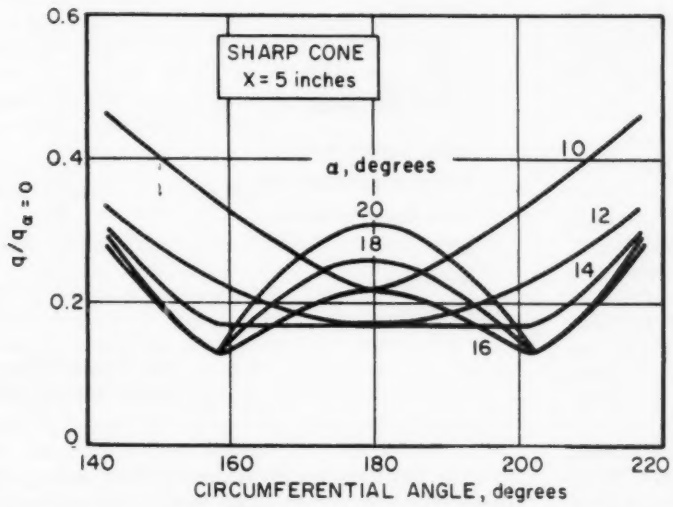


Figure 4. Heat transfer rates in the leeward region of a sharp cone at angle of attack.

Figure 4 shows at several angles of attack the variations of heat transfer rate in the leeward region of a sharp cone. The increased heating locally, in the neighborhood of the leeward meridian, was believed to be associated with the vortex flow resulting from the separated boundary layer. A significant characteristic of this vortex flow field pattern was that increasing the angle of attack caused the heat transfer rate to increase in a situation where the pressure was decreasing.

Additional details of this investigation can be found in Reference 1.

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Mr. Kenneth F. Stetson has been a group leader in the Fluid Dynamics Facilities Research Laboratory at ARL since August 1969. He had been assigned to this laboratory during part of the period in which he was recalled to active duty by the Air Force, 1950-1955, and in 1956 as a civilian. Thereafter he worked on various aspects of the reentry problem with the AVCO Corporation until his return to ARL in 1968 as a Visiting Research Associate of the Ohio State University.

Mr. Stetson received a B.S. degree in Engineering Physics from the University of Maine in 1949 and a M.S. in Aeronautical Engineering from the Ohio State University in 1956. He is also a graduate of the Air Force Institute of Technology (1952).

DOD-SPONSORED RESEARCH AT U. S. ACADEMIC INSTITUTIONS

Dr. William J. Price, Executive Director, AFOSR

In the past three decades in the United States an effective and important working relationship between the Department of Defense and the university research community has come into existence. From this close partnership has developed a vigorous, sustained interchange of ideas, talented manpower, and mutually supportive activity.

For the DOD it means direct and continuing access to scientific training, accomplishment, and progress, accompanied by the personal attention to defense problems of some of the best scientific and technological talent in the country. Strong interactions have resulted between science and technology, with benefits both for the defense establishment and all sectors of the domestic economy.

For universities this means continuing support for basic and applied research as well as exploratory development, and a direct relationship between them and the technological needs of national defense. Increasingly, we see these needs straining the limits of current technology in a manner that does not occur to the same extent in non-defense industrial fields.

For these reasons, the DOD-university research program, and that of the other Federal mission-oriented agencies, should be continually encouraged and strengthened. This does not preclude shifting of funding levels somewhat in times of austerity. They will shift—in fact they already have—but the basic relationship remains productive and must be effectively maintained.

Federal Support of Science—World War II to Today

Department of Defense research support programs began, in response to national needs during World War II, with the Office of Scientific Research and Development under Dr. Vannevar Bush. The Navy opened its Office of Naval Research in 1947, and the Army and the Air Force soon followed with corresponding offices. As the culmination of long planning, the National Science Foundation came into being in 1951 for the support of university research and education in the sciences. NSF research programs were the first to support non-mission-oriented Federal basic research. Other agencies of the United States Government were also supporting university research along the lines of their agency responsibilities; these included the National Institutes of Health, the Office of Education, the Department of Agriculture (long-time research programs), and later, the National Aeronautics and Space Administration. This development enabled the support of university research by a number of different sources of the Federal Government, a concept that has helped to ensure support for a wide variety of research of high quality.

Total Federal obligations for research and development are estimated for fiscal 1970 at about $16 billion. Of this amount, less than 10 percent, or $1.4 billion, goes to academic institutions for performance of research and development. (Table 1) Another $767 million goes to university-affiliated Federally Funded Research and Development Centers (FFRDC). About 16 percent of the total for universities comes from the Department of Defense, or about $223 million; the DOD also provides about $150 million for its Federal Contract Research Centers (FCRCS).

Table 1

FEDERAL OBLIGATIONS FOR UNIVERSITY R&D, FY 70, ESTIMATED BY SELECTED AGENCIES ($U.S. in Millions)

Total		1,418
Total DOD		223
Army	30	
Navy	77	
Air Force	70	
Other DOD agencies	46	
Health, Education & Welfare		617
National Science Foundation		225
Atomic Energy Commission		100
NASA		110
Agriculture		70
All others		73

Note: Excludes FCRCs
Source: BOB Spec. Anal. Q

The DOD portion of university R&D support about equals that of the National Science Foundation. For perspective it must be realized that the figure for NSF represents all basic research—none for applied, and none for development, the costly item. NSF has another $200 million for science education, university development, national research centers, and related programs.

Over the past decade, total Federal support of university research and development has risen far faster than DOD's portion. DOD support has been fairly stable. The important point is that DOD's percentage decrease reflects the growing dependence of universities upon other sources of support. This fact indicates the urgency of making more funds for university research available through agencies such as the National Science Foundation; this trend undoubtedly will continue and even accelerate as more funds for research become available. In 1952 the DOD share of total Federal university support was about half. In 1968 it was about 15 percent. However, most of the growth in Federal funds in recent years has been for fields outside the physical, mathematical, and engineering sciences. DOD still supports perhaps as much as one-half of the Federal total in these areas.

Current DOD Programs

In a letter to Senator Mike Mansfield, dated 4 December 1969, Dr. John S. Foster, Jr., Director of Defense Research and Engineering, described Defense basic and applied research as having three major functions: "to solve recognized technological problems which arise from both short- and long-range military operational requirements; to minimize the possibility of technological surprise; and, as an automatic byproduct of the first two functions, to contribute to the national technical base from which all agencies of the Government, including Defense, ultimately draw their scientific ideas and skilled manpower. . ."

The DOD research program is in 13 scientific disciplines. Universities receive about 40 percent of these research funds, inhouse efforts absorb about 40 percent, and all other account for about 20 percent. In addition, the research program includes Project Themis, conceived and directed to a large degree by DDR&E, and set up to establish new centers of university expertise in selected areas related to defense problems.

DOD-University Mutual Interests

One of the strengths of the DOD-university relationship is that it is built upon mutual understanding and respect for their common interests. The principal function of a university is education of the young men and women needed by society. Knowledge must be transferred to them so that they may both use knowledge and further develop knowledge. The university is clearly the principal agent of society for supplying education. Concomitant with this role is the university role of scholarly research. Research leads to the knowledge and understanding of various phenomena which form the content of science and the foundation of many of the innovations taking place in society.

Universities have a vital role in the problems faced by society. They must emphasize studies and activities which help to assure the future of society as contrasted with the short term problems which are the primary work of government and other non-university activities. Whatever their specific contributions toward solution of problems, this involvement is important in helping assure the relevance of university education, and in assisting in communication between those primarily concerned with generating new knowledge and those using it. This function is particularly important to the engineering and other professional schools, but is also of growing concern to the schools of arts and sciences.

Research support at universities by DOD and other mission agencies is in concert with these university roles. It makes possible a plurality of sources of support for the university researcher, and reduces the possibility that promising research will be overlooked. It also makes available strong and continuing support and interest in particular fields of science and areas of investigation judged to be of interest to both DOD and university scientists. Additionally, support through mission-oriented agencies enables many investigators to relate science, technology, and society in a direct manner often not available to the academic scientist. Many researchers are at their best when confronted with a combination of a desire to know and a need to know. This combination can be a doubly motivating force. Finally, mission-oriented support is important in obtaining adequate funds for university research and graduate education. Adequate research support for university work probably can be attained by appropriations only with a general understanding of why and how the research is important. Funding by a mission-oriented agency often helps explain this need.

Many university professors, in their concern to assure the future of society, desire especially to work on the problems of national security, and particularly on the long-range ones. Academic research can contribute to their solutions in essential ways. University staff members also help provide a bridge between the scientific community with its potentially relevant knowledge and those having need for this knowledge in the applied and development activities necessary for national security.

Thus, by supporting university research in areas judged to be particularly relevant for DOD needs, the defense posture is strengthened through making it possible for some of the country's outstanding scientists and their students to work in areas likely to have great importance for defense. The support assures that both scientific knowledge and educated persons will be available in the scientific fields expected to be most important. In addition, a bridge is maintained between the DOD and the universities, with many resulting benefits to DOD such as the availability of expert consultants.

The DOD administration of the university support programs has been especially designed to assure that mutual interests are optimized. For example, since all university basic research sponsored by the DOD is now unclassified, no requirement exists for prior review. Completely open publication is required either in the scientific literature or in the form of technical reports. Formerly, some projects at universities were classified, mainly to give researchers access to information developed under classified projects, but

ways have been found to permit access as necessary to classified research information. The classification question does arise in exploratory development in certain cases, and occasionally in the application of some of the knowledge gained in basic research. In these instances, no attempt is made to encourage university administrators or faculty members to undertake or to continue classified research projects in opposition to university policy. All DOD-university contracts are with the institution itself, not with an individual researcher.

Administration of DOD Support of Universities

There are more similarities than differences between the research program managements of the Army, Navy, Air Force, ARPA, and other defense agencies. The programs are based primarily on proposals initiated by the universities, designated as unsolicited proposals. The prospective principal investigator submits a proposal through his university in widely circulated fields of active interest indicated by the various DOD agencies. Through this mechanism, a university faculty member can develop a proposed attack on a scientific problem of his own choosing. Typically this is phenomena-oriented research in an area in which the investigator has considerable background. He estimates the duration of his proposed effort, the level of effort in terms of his own and his assistant's time, and the equipment involved. This proposal is then forwarded to an appropriate agency.

His choice of agency to which to send his proposal implies that the agency has done a good job in the scientific community in conveying information on the kinds of research it will support, and particularly the kinds and nature of the problems with which it is most concerned. The investigator is encouraged to discuss his proposed work in advance of submission with the staff of the agency to ensure its compatibility with the agency's research program.

The fundamental selection criteria are headed first by the relevance of the research to agency mission and research program needs. Selection of research areas by the agency is a separate topic to be discussed later.

Among the selection criteria for research proposals are the scientific quality of the work in terms of current scientific problems—is this work at the cutting edge of advancing knowledge. In many instances, proposals are submitted to evaluation panels to gain a wider base of opinion of this scientific excellence. From these evaluations and other comparisons, we know that we are getting proposals which rank with the best of any Federal agency. Other criteria are the qualifications and experience of the research staff, the adequacy of facilities, and the reasonableness of costs. Cost is a matter of negotiation, and of willingness of the proposing institution to cost-share some of the research effort. In this way the Department of Defense receives a high rate of return on its research investment.

Interfacing the DOD-University Research Program with Users

The key to the effectiveness of the DOD research program is communication. The agency sponsoring the research acts as an interface between the researcher and the user. Hence, the staff members of the DOD research agencies must have the mission, the experience, and the techniques required to identify DOD problem areas and to translate them into scientific research opportunities. This interface also functions the other way; that is, to translate scientific knowledge and understanding into results usable by DOD development laboratories, or other DOD contractors, either industrial or non-profit.

By properly selecting research activities to support, we can help assure the availability of especially relevant knowledge when needed, and communication between the scientific community having the knowledge and the technological community having potential use for the knowledge. This latter activity we designate as coupling.

The greatest challenge that research managers face is the selection of areas of research. Selection involves the distribution of research resources among the many possible fields and subfields of science. It is part of the central problem faced in the U.S. Federal science policy and in the science policies of most countries. We need the ability to select what society most needs from all the projects that scientists would like to do.

The Air Force is currently giving particular attention to research planning, establishing approximately 40 research planning objectives in the seven broad areas listed in Figure 1. In each of these areas we are determining the scientific knowledge needed both to support technical planning objectives of the Air Force development organizations and to create new technological opportunities. The latter research requirements are more in the nature of scientific opportunities which have some potential for creating new technological fields for future consideration.

We are relating our scientific program to these research planning objectives in interdisciplinary groupings. Groups of work units for appropriate engineering sciences and more fundamental sciences appear to support specific problem areas. As a thorough analysis is made of the needs for science, including that science with potential for creating substantially unknown technological opportunities, management information is obtained which is useful in deciding program distribution. This type of planning requires careful management for its accomplishment, while at the same time assuring the adequate support of more fundamental work so important to our future technological base.

There are many effective mechanisms for coupling science and technology. In his communication role, the DOD scientist maintains his contacts with the DOD applied research and exploratory development community. Many personal contacts are made by visits, correspondence, special reports, program reviews, and participation in joint task groups.

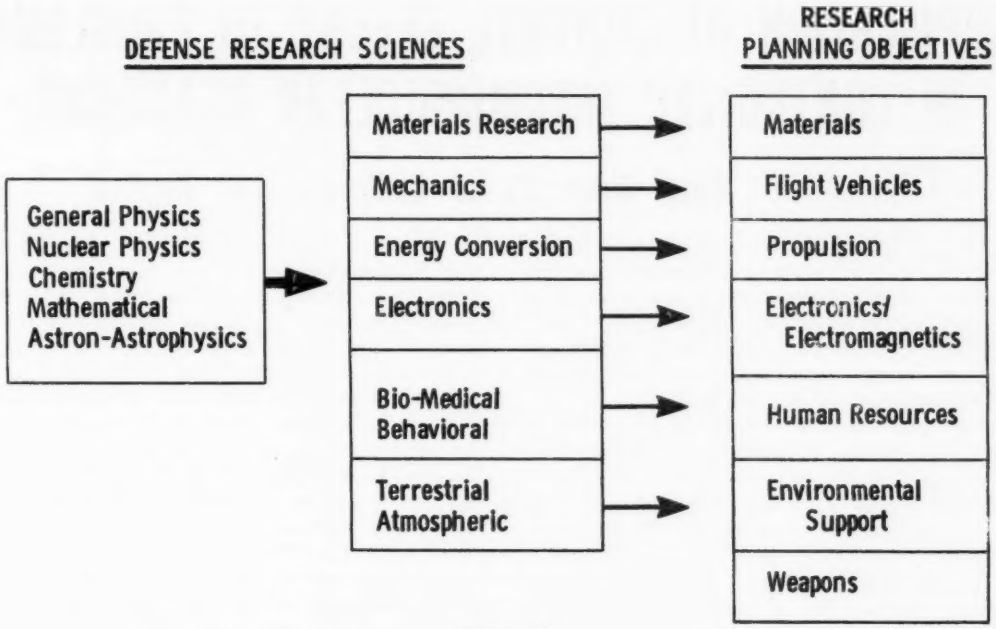

Figure 1

University scientists who have DOD support are able to participate directly in DOD activities in many ways. Among these are consulting visits to DOD installations where they may contribute solutions to pinpointed problems. They also serve as members of ad hoc groups to study feasibility of various exploratory development programs; on state-of-the-art reviews, either oral or written; in special purpose symposia which are specifically designed to bring technologists and scientists together; on special lecture tours; in performance of feasibility studies on research phenomena to put them into more readily usable forms; and in direct consultation with aerospace industries. Many scientists find significant satisfaction and stimulation as they make these important and direct contributions to the Defense establishment, and to the accumulation of basic knowledge.

Some grants and contracts may be thought of as primarily designed to improve our communication with a particularly fast-growing field of science. Many times our resources do not permit us to be pivotal sources of support. But key grants and contracts can give us the insight and first hand knowledge of the field from one or more leaders in that line of research who do keep current. We also sponsor scientific conferences and symposia designed to foster communication within a field and to give us, as project managers, valuable overviews.

Conclusions

The continuance of a strong and effective DOD-university relationship based on cooperation is of the highest importance. There is good reason to believe that the profound nature of the mutual interests will demand it. However, potential misunderstanding in some parts of the Congress, the universities, and the DOD make it necessary to continue to manage the DOD research program in a way that will ensure maximum effectiveness and credibility.

Recent Congressional legislation provides an example of special need for management emphasis. As a result of section 203 of the FY 1970 Military Procurement Authorization Act, we are required to document that the research supported by DOD has "a direct and apparent relationship to a specific military function or operation." The impact of 203 to date has been to cause realignment of some programs, but it is too soon to tell what the requirement will do in terms of long term research goals. The net effect can be to strengthen the impact of the overall program, but careful management will be necessary to accomplish this without permitting the shorter range projects with the more readily recognizable payoffs to squeeze out the more basic research essential for the future.

The DOD is doubly challenged to implement section 203 while at the same time it further develops cooperation based on mutual DOD-university interests. The policy currently being evolved concerning the implementation of section 203 and future restrictions on the use of military appropriations is crucial to the long term continuation of the DOD-university programs.

Contact: Dr. William J. Price
Telephone Extension 44801

APPLICATION OF CONTROL THEORY TO PROBLEMS IN CONTROLLED THERMONUCLEAR REACTIONS

Dr. P.K.C. Wang, University of California, Los Angeles

An important unsolved problem in science and technology today is that of controlled thermonuclear reactions or nuclear fusion. Fundamental is the problem of confining a high temperature plasma long enough for an appreciable number of nuclear fusion reactions to take place. During the past two decades, numerous plasma confinement schemes have been proposed and tested. All these schemes suffer from the problem of plasma leakage as a result of some form of instability or oscillations. Consequently, considerable study of the basic mechanisms of plasma instability has been made in the hope of developing suitable methods for confinement. In most of the proposed schemes, static or quasi-static magnetic field configurations are used for confining the plasma. Although the basic desirable static magnetic field configuration, such as cusp, picket fence, and mirror geometries, have not altered much since their first proposal, significant modifications have been made as a consequence of recent theoretical and experimental advances.

A notable contribution has been made by Ioffe and his co-workers who experimentally demonstrated (using a combined mirror and cusp geometry) the improvement in plasma confinement in a region where the vacuum magnetic field has a minimum (the "minimum B" principle) (1).

During the past five or six years, an attempt has been made to use high-frequency electromagnetic fields for plasma confinement. This approach has stimulated numerous theoretical and experimental studies on the interaction of plasmas with high-frequency electromagnetic fields (2).

Recently, various proposals have been made for using feedback to quench certain forms of plasma oscillations such as electrostatic oscillations (3,4). Experiments using a simple form of feedback showed considerable improvement in plasma confinement for certain types of systems (4).

At the present time, studies on the feedback stabilization of plasmas are being actively pursued both in this country and in the Soviet Union.

During the past year or so, studies on various theoretical aspects of stability and control of systems with distributed parameters have been made at the University of California, Los Angeles, under a grant from the Applied Mathematics Division of the Air Force Office of Scientific Research. A portion of these studies is devoted to exploring the application of control theory for distributive systems to problems in thermonuclear plasma confinement. The investigations are made using both microscopic and macroscopic mathematical models for the plasma.

In the microscopic model, the plasma is described by the Boltzmann-Vlasov equation along with the Maxwell equations describing the electromagnetic fields. Here, the plasma confinement problem is posed as an optimal control, or a variational problem in which the confining external electromagnetic field is the unknown control variable. A particular version of the plasma confinement problem considered is that of determining an external electromagnetic field in a certain admissible class in a manner that maximizes a weighted time average of the total number of particles in a given spatial confinement region over a specified time interval. This problem is motivated from the physical situation where a thermonuclear reactor operates in a pulsed mode; i.e., a certain amount of hot plasma is injected into a given confinement region at the beginning of the pulse cycle and the external electromagnetic field is manipulated so as to retain as many particles as possible over the pulse duration. For this problem, necessary conditions for optimality and also the existence of optimal controls have been established for the cases where the external electromagnetic fields are spatially uniform but time-varying. See references (5,6) for details.

In the macroscopic model, the plasma is considered as a conducting fluid whose motion is governed by the magnetohydrodynamic equations. Here, plasma confinement is posed as a stabilization problem. Particular attention is focused on the use of feedback to stabilize the unstable equilibria of the system. The feedback is in the form of perturbations of the external magnetic field about a given static field configuration that depends on the plasma boundary surface displacement about its equilibrium. The motivation for this approach is based on observations in several types of machines in which variations of 0.1 percent or less in the static magnetic field distribution can have profound effects on the plasma confinement. This high sensitivity of the system behavior with respect to the magnetic field distribution is particularly favorable for the effective use of feedback control. Recently, a general form of feedback for local stabilization has been obtained, using the linearized magnetohydrodynamic equations for a highly conducting plasma. An explicit form of feedback control has been derived for a linear pinch with a uniform axial static magnetic field. The details are described in reference (7).

At present, further studies are being made on the foregoing problems, taking into account various physical constraints such as limitations in measurement and in the physical realization of the control forces. Some numerical

experimentation, associated with certain plasma systems in the presence of various forms of controls, is also in progress. The numerical results should provide better insight into the merits of the proposed approaches and also serve as a guide for planning physical experiments.

Contact: Major A. D. Dayton, AFOSR
Telephone Extension 45261

Dr. P. K. C. Wang is an Associate Professor at the School of Engineering and Applied Science, University of California. He received his B.S. in June 1955 and his M.S. in June 1956, both in Electrical Engineering from the California Institute of Technology. In January 1960 he earned a Ph.D. in Electrical Engineering from the University of California at Berkeley.

Dr. Wang is the winner of two "best paper" awards: one in 1961 from the Applications and Industry Division of the AIEE and one in 1964 from the IEEE's Professional Group on Automatic Control. He has published more than 50 papers and is considered a leader in the field of control of distributed parameter systems.

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USE OF SATELLITES IN EARTHQUAKE DETECTION*

Ionospheric Physics Laboratory, AFCRL

The first use of a satellite for earthquake detection has been reported by two AFCRL scientists. Of course, earthquakes can be detected more directly and efficiently by other means, but the fact that a satellite could have such a role is noteworthy, and could prove of interest to seismologists. Dr. Terence J. Elkins and Frederick F. Slack detected the earthquakes while conducting research on ionospheric perturbations.

Two major earthquakes were detected: one occurring in the Caribbean on December 25, 1969; the other, in Southeast Asia on January 3, 1970. The detection was made by a new, extremely sensitive radio interferometer at AFCRL's Sagamore Hill Radio Observatory in Hamilton, Mass. The VHF interferometer, operating with a 10 km baseline, measures changes of ionospheric refraction as small as 1 second of arc by monitoring beacon transmissions from geo-stationary satellites. When an earthquake occurs, the seismic waves launch acoustic (pressure) waves into the atmosphere. These acoustic waves are propagated upward to the ionosphere to create ionospheric perturbations. The interferometer detects the small refraction changes in the satellite signal path caused by these perturbations.

Although the efficiency of the earth-ionosphere coupling is very low, the interferometer was able to detect the seismic pulse in the ionosphere on at least five separate trips around the earth.

Contact: Dr. Terence Elkins
Telephone Extension 2940

Dr. Terence J. Elkins has been employed in the Radio Astronomy Branch of AFCRL's Ionospheric Physics Laboratory since 1961. Currently, he is making studies, using stationary satellites, of ionospheric irregularities and F region drifts.

Dr. Elkins received a B.E.E. from the University of Melbourne in 1958. From Boston University he earned an A.M. in Physics and Astronomy in 1967 and a Ph.D. in 1969. He is a member of Signa Xi and has published several articles on his work.

Originally presented in more detail at the NATO Defense Research Group Seminar on Cooperation Between Defense Research Establishments, Universities, and Industry; Dusseldorf, 21-23 April 1970.

ELECTRIC FIELD STRUCTURE IN AN ELECTROFLUID DYNAMIC (EFD) GENERATOR

John E. Minardi, University of Dayton, Ohio

Electrical breakdown of the working gas is an important limitation of the power output of an EFD generator operating with colloids. A detailed knowledge of the potential and the magnitude of the electric field intensity is needed to determine theoretically the conditions which will produce breakdown in a given generator design and the operating conditions which will yield the maximum power output for the design while avoiding breakdown. These detailed data are also useful for design modifications and for new generator designs.

The University of Dayton Research Institute in collaboration with ARL has developed a computer program which can determine lines of constant potential and lines of constant magnitude of the electric field intensity for both axisymmetric and two-dimensional (Cartesian) EFD generators operating with colloids. An early version of this program is documented in an ARL report (1); examples of studies of ARL experimental generators performed with the program are given in (2,3).

The viscous coupling of charged colloid particles to the neutral gas prevents any significant motion of these particles due to the electric field, (2) which permits the uncoupling of Poisson's equation from the continuity of charges. This uncoupling permits the charge density distribution to be determined from fluid mechanics and the density distribution to be treated as an input to the computer program which solves Poisson's equation. The uncoupling also permits numerical superposition to be used to generate composite solutions by simply multiplying basic solutions by scale factors and adding. Thus, parametric studies, which vary the applied voltages and the initial charge density, are easily performed for a given geometry. The basic solutions are obtained for these conditions: one volt applied to a single electrode, zero volts specified for all remaining electrodes, and a uniform charge density of zero. These basic solutions are obtained for each of the electrodes. Finally, a solution is obtained for a specified charge distribution with zero volts on all the electrodes and an arbitrary initial charge density. The potential at any point within the channel is then obtained from the equation

$$U = \sum_{i=1}^{m} S_i \varphi_i + S_p \varphi_p \qquad (1)$$

where U is the potential at the point in question, φ is a potential obtained from a given basic solution and S the corresponding scale factor which produces the desired applied voltage on a given electrode or charge density in the channel. The i subscripts correspond to the basic Laplace solutions (no space charge), and the p subscripts refer to the basic Poisson solution (desired charge distribution and zero volts on all electrodes).

In general, the value of the magnitude of the field intensity will not be a linear combination of the values in the basic solutions at an interior point of the channel. However, on the surface of an electrode the magnitude of the field intensity will be a linear combination of the basic solutions, as all the vectors of the field intensity are normal to the surface of an electrode.

The results of the computer program indicate that the maximum value of the magnitude of the field intensity is at a point on the surface of an electrode; hence, the maximum can be determined as a linear combination of the basic solutions. By taking the derivative of equation (1) in a direction, n, normal to the surface of the electrode we obtain

$$\left|\frac{dU}{dn}\right| = \left|\sum_{i=1}^{m} S_i \frac{d\varphi_i}{dn} + S_p \frac{d\varphi_p}{dn}\right| \qquad (2)$$

where $|dU/dn|$ is the magnitude of the field intensity at a given point on the surface and the values of the various $d\varphi_i/dn$ and $d\varphi_p/dn$ can be determined at this given point from the basic solutions.

A parametric study, performed by varying the scale factors S, indicates the location of various critical points (i.e. points of maximum magnitude of the field intensity) for which the linear equation in the scale factors, equation (2), can be explicitly evaluated. These equations can then be used to determine the theoretical performance of the particular configuration over a wide range of applied voltages and initial densities.

A typical composite solution is shown on figure 1 for an ARL experimental two-dimensional configuration which was obtained from an automatic plotter. Lines of constant potential are shown in the plot on the left and lines of constant magnitude of the electric field intensity are shown in the plot on the right. This solution was generated from six basic solutions.

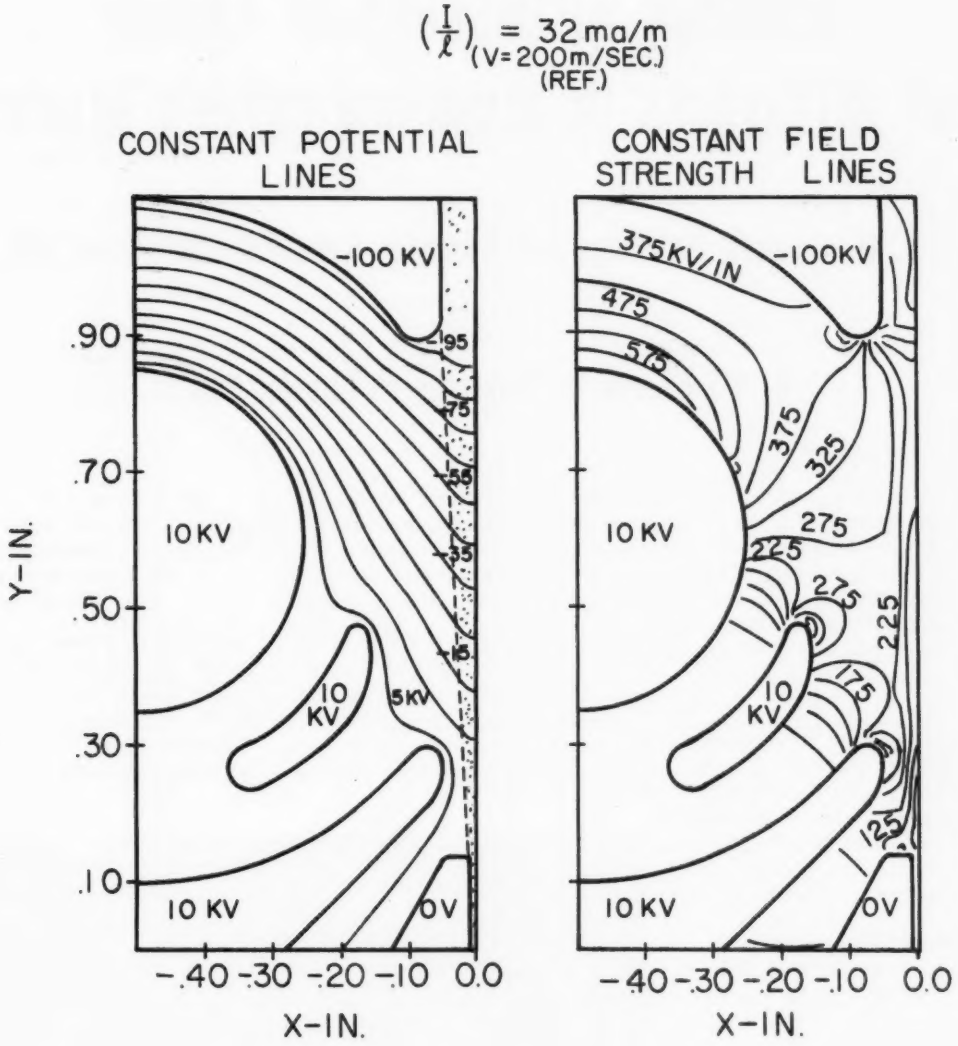

Figure 1. Composite Laplace-Poisson plots for a two-dimensional conversion section.

The program as presently constituted permits the detailed study of the electric field structure in an axi-symmetric and two-dimensional EFD generator of rather complex geometry over a wide range of generator variables. For improved prediction of breakdown within the channel, especially in the ARL two-fluid case, future work will include preparation of both charge density distributions and gas density distributions from a turbulent jet mixing program such as that described in (4).

Contact: Lt. Col. William N. Jackomis, ARL
Telephone Extension 53222

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ELECTRON MICROSCOPY OF LEDGES AT INTERFACES IN ALUMINUM-COPPER ALLOYS

C. M. Sargent, Metallurgy and Ceramics Research Laboratories, ARL

and

G. W. Weatherly, University of Toronto, Canada

The strength of a precipitation-hardened alloy depends upon the size and distribution of second-phase particles. Since growth (coarsening) of the particles affects the strength properties, a knowledge of the mechanism of growth of precipitates is important in predicting the stability of a microstructure.

J. W. Cahn (2) and H. I. Aaronson (1) have shown that small faceted precipitates with planar interfaces, whose orientation corresponds to pointed minima on the γ-plot (interface energy versus orientation) must grow or dissolve by the formation and lateral migration of ledges. Ledges are observed at the interfaces of θ' precipitates in an Al-4% Cu alloy where two plates impinge during growth. These ledges have been interpreted as growth steps (4). A detailed study of the electron microscope images of ledges on precipitates enables the sense of the ledge to be determined, i.e. whether it is in fact a growth or a dissolution ledge, and whether the ledge lies at the top or bottom surface of the precipitate platelet.

The ledges are visible when either a matrix or precipitate reflection operates. They are most clearly visible when electrons are diffracted by the precipitate to form an image and appear as black or white lines (figure 1). The images are wide (up to 300Å) and oscillate from black to white as the precipitate is tilted through the exact Bragg diffracting position. The dominant feature of a circular step is that the contrast changes from black to white on opposite sides of the step.

Using the approximation of the strains around the ledge as equal to those of a prismatic dislocation loop, the Howie-Whelan electron diffraction equations (3) were numerically integrated for the approximate contrast conditions:

$g = 112\theta'$ (g is the reciprocal lattice vector of the diffracting planes)

$w = +1.7$ (w is the deviation from the Bragg angle)

The results of these calculations are shown in figure 2. The images are white on one side of the loop and black on the other, as observed. A schematic diagram of the contrast from complete loops is shown in figure 3.

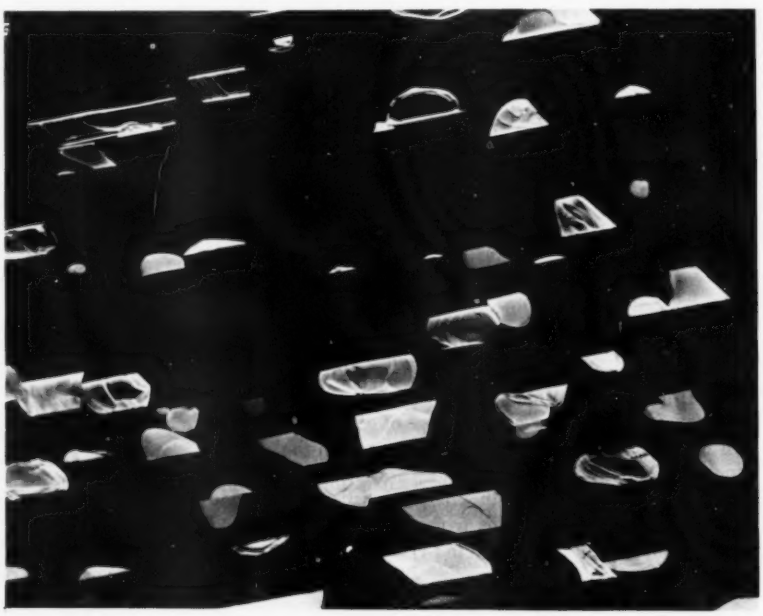

Figure 1. Electrons diffracted by the precipitate to form an image.

The nature of the ledges and their position relative to the precipitate can be determined from the contrast. (The key feature is the "cross-over" of the image from white to black.) For instance, the ledges shown in figure 1 are growth ledges lying at the bottom of the precipitate.

Hence, careful electron microscopy can be used to determine whether an individual particle is growing or dissolving.

Contact: Mr. C. M. Sargent
Telephone Extension 54788

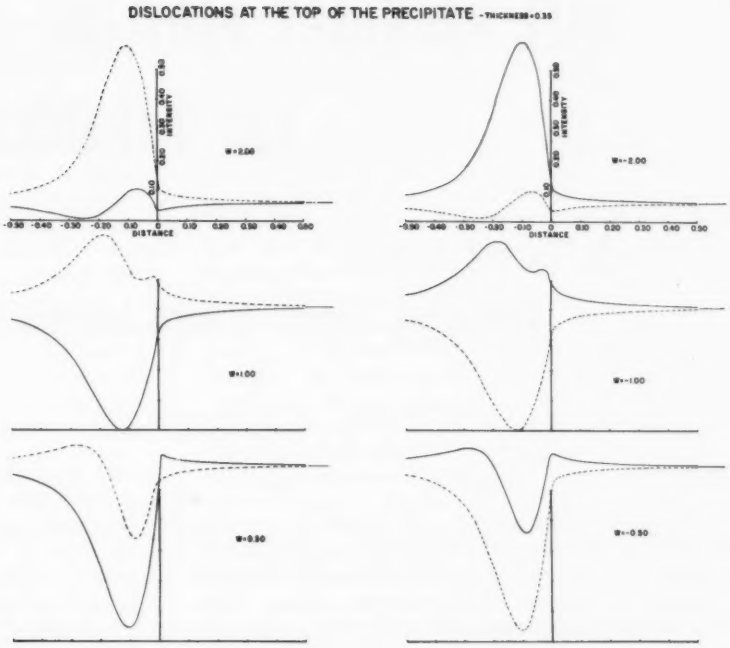

Figure 2. Dislocation at the top of the precipitate. Thickness = 0.35

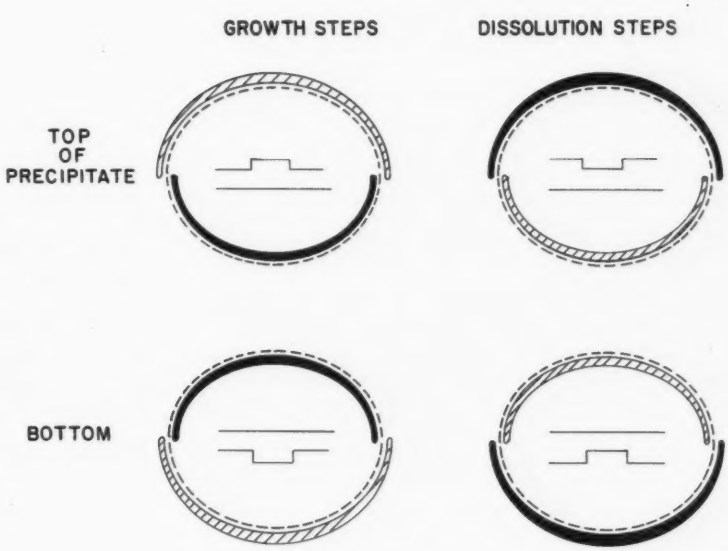

Figure 3. Schematic diagrams of the contrast from complete loops.

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Mr. Colin M. Sargent has been with the Metallurgy and Ceramics Research Laboratory of ARL since July 1967. He is investigating the role of coincident lattice properties in controlling the production of recrystallization textures. A program is in progress dealing with the propagation of a stress-corrosion crack along a grain boundary in high strength aluminum alloys.

Mr. Sargent received his B.A. in 1961 and his M.A. in 1967, both from Cambridge University, England. Late in 1966 he came to the United States to work for the Ohio State University Research Foundation which assigned him to ARL as a research metallurgist, specializing in the use of the electron microscope.

FREE BOUNDARY PROBLEMS FOR PARABOLIC EQUATIONS

Dr. Bernard Sherman,

Rocketdyne Division of North American Rockwell Corporation

Introduction

The problems of science and technology are often formulated mathematically as partial differential equations, particularly in such areas as fluid mechanics, elasticity, electromagnetic theory, and conduction of heat. These partial differential equations are examined in a region of a space of two or more dimensions, with specifications of expressions involving the unknown and its derivatives on part or all of the boundary of that region.

An example is the equilibrium temperature in a bounded three-dimensional region R when the temperature on the bounding surface S of R is prescribed as a function f(P) of position P on that surface. Whatever the initial distribution of temperature in R, an equilibrium temperature u(x,y,z) will ultimately be reached at each point (x,y,z) of R, and this temperature will be subject to Laplace's equation $u_{xx} + u_{yy} + u_{zz} = 0$ (here the subscripts indicate two partial derivatives with respect to the indicated variables) in R as well as the boundary condition u(P) = f(P) for all points P of S. This is the Dirichlet problem, or first boundary value problem, for the Laplace equation. This problem can be solved explicitly for sufficiently simple surfaces and boundary conditions and, in general, it is known to have a unique solution for reasonably smooth surfaces S.

Partial differential equations can often be classified according to type as elliptic, hyperbolic, and parabolic. A discussion of the method of arriving at this classification appears in reference (4). The Laplace equation is the classical example of an elliptic equation, whereas the wave equation, governing wave propagation, is the typical example of a hyperbolic equation. The heat equation, governing the phenomenon of heat conduction when time is taken into account, is the typical example of a parabolic equation. A problem leading to the heat equation in one space variable is the following: A slab, occupying the entire region $0 \leq x \leq a$ of three-dimensional space, has an initial temperature g(x). The faces x = 0 and x = a are kept at prescribed temperatures $f_1(t)$ and $f_2(t)$. It is physically clear that the temperature u(x,t) at position x in the slab at time t is uniquely determined. Indeed it is the solution of the heat equation $u_{xx} = u_t$ (we take the thermal diffusivity to be 1) in the region $0 \leq x \leq a$, $t \geq 0$ of the (x,t) plane subject to the conditions $u(x,0) = g(x)$, $u(0,t) = f_1(t)$, and $u(a,t) = f_2(t)$ on the boundary of that region.

A free boundary problem for a partial differential equation arises when the region in which the partial differential equation is to be solved is not entirely specified. Part of the boundary of that region has to be determined along with the unknown. These problems arise in many areas of science and technology. Two such problems, of particular interest to the Air Force, are the blunt body problem and the ablation problem. The blunt body problem concerns an axially symmetric body immersed in a hypersonic flow parallel to the axis of symmetry. A detached shock wave forms in front of the blunt body and there is a region of subsonic flow between the shock wave and the blunt body near the axis of symmetry. We wish to determine the shock wave and the subsonic flow regime; i.e., velocity, pressure, density, and temperature. The partial differential equation governing the subsonic flow is elliptic, but the region in which it is to be solved, the region between the shock wave and the blunt body, is not specified in advance because the shock wave which is not known, has to be determined. The shock wave is the free boundary.

In the ablation problem the surface of the ablating shield is a function of time. It is this function of time that is the free boundary. Later, a simple model of ablation will be discussed in greater detail.

Free Boundary Problems for Parabolic Equations

Free boundary problems for parabolic equations arise in heat conduction with melting, condensation of droplets in a saturated vapor, formation of gas bubbles in a liquid, diffusion with chemical reaction, control theory, and Markov processes. A problem of this sort is the following: Suppose the region $0 \leq x \leq a$ is occupied by the liquid

phase of some material with an initial temperature distribution $g(x) \geq 0$, $g(a) = 0$, where the melting temperature is 0, and suppose the region $a < x < \infty$ is occupied by the solid phase of the same material at the melting temperature. We suppose the densities of the liquid and solid phases are the same. Now if $f(t) \geq 0$ is the prescribed temperature at the fixed face $x = 0$, then it is physically clear that the interface between the liquid and solid phases, which is initially at $x = a$, will advance to the right as the solid is melted and changed to liquid. Thus the moving interface will have a time history $x = s(t)$ which is not known to us and has to be determined along with the temperature $u(x,t)$ at position x of the liquid phase at time t. The temperature $u(x,t)$ satisfies the heat equation $u_{xx} = u_t$ in the region $0 < x < s(t)$, $t > 0$ of the (x,t) plane and also satisfies obvious boundary conditions on the t-axis and on the segment $0 \leq x \leq a$ of the x-axis. Along the curve (the free boundary) $x = s(t)$ we have the obvious condition $u[s(t),t] = 0$. If $s(t)$ were known, these boundary conditions, together with the heat equation, would be sufficient to determine $u(x,t)$. Since $s(t)$ is now known, it is clearly necessary to introduce an additional condition on the free boundary in order to make the problem fully determinate. This additional condition is a conservation of energy condition involving the latent heat, $\rho \ell s'(t) + k u_x[s(t),t] = 0$, where ρ is the common density of liquid and solid, ℓ is the latent heat, and k is the thermal conductivity of the liquid. The problem for the two unknowns $u(x,t)$ and $s(t)$ is now fully formulated.

This problem may be modified and extended in various ways. We could, for example, specify the flux of heat at the fixed face $x = 0$, rather than the temperature. We could introduce an initial temperature distribution in the solid phase so that we have a two-phase problem. The problem discussed above is a one-phase problem in the mathematical sense that the temperature in the solid phase is always zero and therefore can be ignored. In a two-phase problem we have two temperatures to determine, $u_1(x,t)$ in the liquid phase and $u_2(x,t)$ in the solid phase, as well as the free boundary $s(t)$. The formulation of the two-phase problem is straightforward; again there is a conservation of energy at the free boundary.

An interesting extension of the problem discussed above involves the introduction of a flux of heat $q(t)$ in the moving interface. Of course it is not physically possible to realize the introduction of such a heat flux, but mathematically it requires simply the replacement by $q(t)$ of the term 0 on the right side of the conservation of energy condition. This problem can, under certain conditions, be interpreted as a crude model of ablation. More precisely, suppose the region $0 \leq x \leq a$ is solid with the initial temperature $g(x) \leq 0$, $g(0) = 0$, and the region $a < x < \infty$ is liquid at the melting temperature 0. There is prescribed flux $f(t)$ at the fixed face $x = 0$ which, for the purposes of an ablation model, we can take to be 0. Thus the fixed face is insulated—no heat flows across it. Now we assume the flux $q(t)$ in the moving interface to be directed into the solid and to be of such magnitude that the moving interface always moves to the left; i.e., $s(t)$ is a decreasing function of t. Then we can interpret the region $0 \leq x \leq a$ as a heat shield and the flux $q(t)$ as the agent of ablation. Since $q(t)$ is always at the moving interface, we may think of the melted material as being instantaneously removed. In this model $s(t)$ is the time history of the exposed face of the heat shield and $u(x,t)$ is the temperature distribution in it at time t.

The free boundary problems for parabolic equations discussed above, as well as gas bubble and droplet problems, have in common the characteristic that one of the conditions at the free boundary $s(t)$ involves the derivative $s'(t)$ in a simple, explicit manner. These problems are nonlinear even though the partial differential equations are linear (there are examples where they are nonlinear), since the principle of superposition does not apply. In recent years a comprehensive mathematical theory has been developed for these free boundary problems. The theory is concerned with the question of their well-posed nature; i.e., existence, uniqueness, and continuous dependence on the data. Further questions concern the smoothness of the free boundary, and the behavior of the free boundary near $t = 0$ and for large t. It has been proved for many of these problems that they are well posed. For problems in which there is no flux $q(t)$ in the moving interface, it has been proved that the free boundary $s(t)$ is infinitely differentiable. Explicit solutions are available for only a few problems with the simplest initial and boundary conditions. Effective numerical procedures have been devised for these problems.

Free Boundary Problems and Brownian Motion

A class of free boundary problems for parabolic equations which does not share the essential characteristic of the problems described above, the explicit appearance of a term involving the derivative of the free boundary, occurs in connection with Markov processes. It will be sufficient for this discussion to confine our attention to a particular example of a Markov process, the Brownian motion process, also frequently called the Wiener-Levy process. The one-dimensional Brownian motion process $x(t)$ is defined by the properties: first, increments of position $x(t)$ over non-overlapping time intervals are independent (in the probability sense) and second, the distribution of $x(t_2)-x(t_1)$ is normal with mean zero and variance $\sigma|t_2-t_1|$, where σ is a fixed constant. It is also usually assumed that $x(0) = 0$.

The Brownian motion process has the fundamental property that the Brownian paths are continuous (with probability 1). This was first proved by Norbert Wiener in 1923. It is possible then to regard the Brownian motion process as a model of the physical Brownian motion, at least to a first approximation. The relationship of the Brownian motion process to the heat equation is a consequence of the fact that the density function of the random variable $x(t)$ is a solution of the heat equation.

An example of the type of free boundary problem arising in connection with Brownian motion is the following sequential analysis problem discussed at some length by

Herman Chernoff of Stanford University. Suppose we have a one-dimensional Brownian motion $x(t)$ with drift μ per unit time. Thus we observe $\mu t + x(t)$. The drift μ has a known prior distribution which is normal with mean μ_0 and variance σ_0^2. As the process unfolds, the prior distribution becomes a posterior distribution by virtue of the information we are receiving. Indeed it can be shown that if we start the process at $x = \mu_0/\sigma_0^2$ at time $t = 1/\sigma_0^2$ then, if we observe the random point in position x at time t, the posterior distribution of μ is normal with mean x/t and variance 1/t.

We want to test the hypothesis $\mu \geq 0$ against the alternative $\mu < 0$ subject to the conditions that the cost of observing is proportional to the time of observing and the cost of a wrong decision is proportional to $|\mu|$. By a test we shall mean a pair of curves $s_1(t)$ and $s_2(t)$ in the (x,t) plane such that $s_1(t) < s_2(t)$ and a pair of curves which we use for test purposes as follows: if the initial point $(\mu_0\sigma_0^2, 1/\sigma_0^2)$ lies on or to the right of $s_2(t)$, we accept $\mu \geq 0$; if it lies on or to the left of $s_1(t)$, we accept $\mu < 0$; and if it lies between the curves, we observe the graph of the process [graphed in the upward direction from the point $(\mu_0/\sigma_0^2, 1/\sigma_0^2)$] until one of the curves is hit. If $s_2(t)$ is hit, we accept $\mu \geq 0$ and if $s_1(t)$ is hit, we accept $\mu < 0$. In the region between the curves there is a function $B(x,t)$, called the Bayes risk, which is the expected cost of further observation plus the expected cost of a wrong decision when the random point is at position x at time t. Chernoff has shown that $B(x,t)$ satisfies a parabolic equation subject to the boundary conditions $B(s_1(t),t) = D(s_1(t),t)$ and $B(s_2(t),t) = D(s_2(t),t)$, where $D(x,t)$ is the expected cost of a wrong decision; $D(x,t)$ is easily determined from the posterior distribution of μ. $B(x,t)$ is determined in $s_1(t) \leq x \leq s_2(t)$ by the parabolic equation and the boundary conditions, and we assume $B(x,t) = D(x,t)$ outside of this region.

Now a free boundary problem arises when we seek to choose $s_1(t)$ and $s_2(t)$ so that $B(x,t)$ is uniformly minimized for all x and t. As the function $D(x,t)$ is an even function of x, it is plausible that, if an optimizing solution exists, then the curves $s_1(t)$ and $s_2(t)$ are mirror images across the t-axis, say $\pm s(t)$. Chernoff has shown that if there is an optimizing solution, then the two surfaces $B(x,t)$ and $D(x,t)$ not only coincide along $\pm s(t)$ but coincide smoothly: $B(\pm s(t),t) = D(\pm s(t),t)$ and $B_x(\pm s(t),t) = D_x(\pm s(t),t)$. Thus the optimizing solution turns out to be the solution of a free boundary problem for a parabolic equation.

There is no comprehensive theory of the type of problem described above in connection with Brownian motion nor, in general, for the type of free boundary problem in which the derivative of the free boundary does not appear explicitly. Such a theory may be expected to emerge in the next few years.

References to the Literature

The author has worked on free boundary problems for parabolic equations under contract no. AF49(638)-1679 of the Air Force Office of Scientific Research since February 1966. Many of the results of this effort are reported in (5,6,7,8), papers that contain a large number of references to recent work in the field. We mention also the books of Carslaw and Jaeger (1) and Friedman (3), each of which has a chapter on free boundary problems for parabolic equations. For the free boundary problems arising out of Markov processes, we refer to Chernoff (2). For the free boundary problems of fluid mechanics (the equations are not parabolic), we refer to (4).

Contact: Lt. Col. William R. Trott
Telephone Extension 45264.

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Dr. Bernard Sherman is a member of the technical staff of the Rocketdyne Division of North American Rockwell. His duties there include mathematical research and consulting.

He obtained his B.A. in Physics in 1940 from Brooklyn College and his Ph.D. in Mathematics in 1949 from Princeton. He has taught at the Universities of Vermont, Southern California, and California (Berkeley and Los Angeles) and has worked at the Westinghouse Research Laboratories and at TRW Systems.

Dr. Sherman's research, published in several mathematical and statistical journals, has been in applied mathematics, stochastic processes, and theoretical statistics. He is a member of the American Mathematical Society and the Institute of Mathematical Statistics.

RESEARCH FOR IONOSPHERIC FORECASTING

Col. Robert B. Kalisch, Ionospheric Physics Laboratory, AFCRL

In 1969 the Air Weather Service (AWS) reiterated their requirement for an ionospheric forecasting capability to support current and future activities of ADC, SAC, TAC, MAC, and AFSC. AWS solicited the support of AFCRL in finding solutions to a number of specific problems posed by ionospheric forecasting because AFCRL already had several such projects in progress. The transition of these independent projects from basic research into an AWS-oriented program is the subject of this article - a problem that may be of interest to research planners in other disciplines.

Timing

The time phasing between a requirement and a research program is a critical problem. Many research efforts needed by AWS would take four or more years to produce usable results. In some cases research is requested to support systems already in limited operational status. If the need is immediate and the research might require four years, a serious question exists about the advisability of pursuing the research. In this program, the highest priorities were given to areas in which a typical research cycle of several years could produce a timely result.

Levels of Involvement

Three levels of research involvement with AWS characterize the program: At the first level are several research projects initiated solely to provide information for AWS; these must be strongly indorsed by AWS in order to continue. This class of research offers promise of quick results with rapid utilization of the newly gained knowledge.

At the second level of involvement is research which satisfied the Ionospheric Physics Laboratory needs; this work was initiated because the research scientists forecast Air Force needs in these areas. Now this research appears to have direct relevance to specific AWS needs. Most research on problems of ionospheric forecasting falls into this category.

Our lowest level of involvement consists of those research efforts dealing with methodology or phenomena which do not now appear to be directly related to ionospheric forecasting, but whose relevance may increase as the research progresses. In retrospect, this type of research may turn out to be the most creative; these are the long shots – low probability of payoff, but with such a high payoff when successful that they must be included in a balanced program.

Program Needs

Conceptually, the ionospheric forecasting capability of AWS depends upon sensors collecting data, the reporting of these data to an integration center, integration of the data, and specific forecasting techniques. The Ionospheric Physics Laboratory program deals with each of these prerequisities for forecasting.

Sensors. AWS requires a set of sensors that will adequately define the ionosphere for worldwide forecasting purposes. Varying densities of ionospheric data are required to support the various AWS consumers. For example, particular systems require a narrow geographical coverage, but a detailed knowledge of the ionosphere as compared to SAC aircraft communications.

The ultimate AWS type of sensor array will be determined by the forecasting techniques adopted. AWS is at this time still interested in a broad class of ionospheric sensor systems - conventional ground-based ionosounders, riometers, solar microwave systems, and airborne sounders.

Typical sensors systems being developed or used are riometers, low frequency sounders, a VLF sounder, an airborne Granger sounder, and both airborne and ground digital sounders. Measurements are regularly made and analyzed on total electron content, scintillation, and the spectral distribution of microwave solar radiation. A newly initiated program treats polarization signatures of microwave solar radiation.

A variety of sounders is required to obtain data over a wide range of electron densities. Since many interactions between density levels are not well understood and important physical phenomena take place at various levels, the research program must be capable of investigation anywhere in the ionosphere. An example is the prediction of the usable radio frequencies for oblique propagation, which is of great interest to the AWS. Operational systems require such estimates, but no direct reliable technique exists to provide them. Data from the lower ionosphere (D region) are needed because most radio wave absorption occurs here; upper ionospheric data (F region) are essential because this region constrains the frequencies which will be reflected by the

ionosphere.

The Air Weather Service must be cognizant of ionospheric sensors across the spectrum, so that it can deploy and operate the equipment best suited to specific USAF consumer needs. Therefore, equipment such as the new AFCRL VLF sounder is of interest to AWS, even though it may not have an immediate application.

Reporting. Obviously, data collected from a worldwide array of sensors must be reported to a central facility. The most common means of ionospheric specification today is the electron density profile. When these profiles are obtained at many different locations, a major data transmission problem exists, particularly if a real-time reporting/forecasting capability is required.

Ongoing research at the Ionospheric Physics Laboratory deals with the problem. The plan is to digitize the basic ionogram or its processed counterpart, the electron density profile, and then develop a suitable code for high speed automatic transmission. Symbols are used so that the overall visual impression conveys the data as well as the symbols themselves.

See figure 1 for the use of the printed area as a measure of intensity. This system, devised by Dr. Bibl at Lowell Technological Institute in cooperation with AFCRL, offers promise of efficient "pro forma" data transmission.

The art of developing techniques to handle the specific parameters required for forecasting is still in its infancy, but will be a major growth area as the problem evolves.

Data Integration. The most challenging of all problem areas is probably data integration. The need is to combine a number of independent

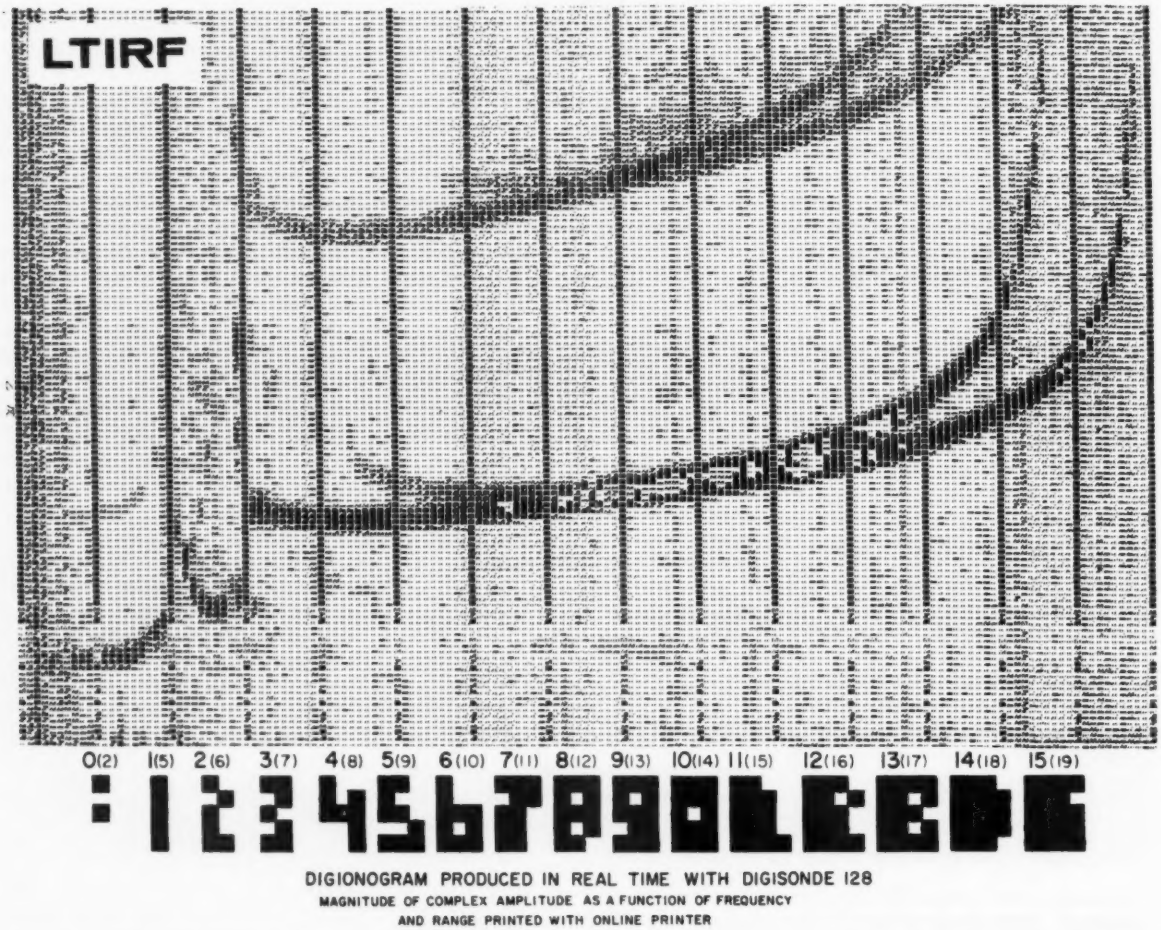
LTIRF
0(2) 1(5) 2(6) 3(7) 4(8) 5(9) 6(10) 7(11) 8(12) 9(13) 10(14) 11(15) 12(16) 13(17) 14(18) 15(19)
DIGIONOGRAM PRODUCED IN REAL TIME WITH DIGISONDE 128
MAGNITUDE OF COMPLEX AMPLITUDE AS A FUNCTION OF FREQUENCY
AND RANGE PRINTED WITH ONLINE PRINTER

Figure 1. Digital pattern printout of data generated with Digital Integrating Goniometric Ionosonde, developed for three branches of AFCRL by Lowell Technological Institute Research Foundation, Lowell, Mass. The digital patterns are generated for any 3- or 4-dimensional presentation of digital data, for example, amplitude and phase of echo pulses as function of frequency and range.

These digisondes are being used as precise and sensitive radio echo sounders for supplementing rocket release and rocket probing experiments, as an airborne ionosonde, and as the first remotely monitored ionospheric reference station usable for forecast and warning.

observations to give the forecaster an overview of the critical parameters.

AFCRL recently initiated a project for the areal mapping of the ionosphere. Under the direction of Dr. Charles Rush, a number of parameters from geographically dispersed stations will be collected and used to map ionospheric features such as critical frequencies, electron density levels, or total electron content. The region between readings will be interpolated according to physical intuition.

These ionospheric maps will be the starting point for more detailed investigations. After some experience in observing ionospheric disturbances propagating over the instrumented region, Dr. Rush hopes to develop techniques of forecasting the magnitude and type of change occurring in the ionosphere under specific conditions. This study is motivated by the weather-map approach to meteorological forecasting. If ionospheric "fronts" can be defined, ionospheric forecasting by areal mapping could become a reality.

Another important effort in data integration is the computer processing of digital sounding results to provide parameter extraction. Computer programs are being written and tested at AFCRL to provide for the automatic display of such parameters as MUF (maximum usable frequency) and layer heights.

Forecasting Techniques. The Ionospheric Physics Laboratory has a number of research projects which are devising forecasting methodology. Probably the best known work is the solar forecasting at the Sagamore Hill Radio Observatory. Mr. J. P. Castelli developed spectral radiation criteria for solar microwave emissions. These criteria have been effective in detecting which solar flares will produce major proton events. Other parameters are under study to improve the criteria. One investigation deals with the delay time between burst initiation and the maximum; another, the analysis of integrated pulse power as a function of proton flux. Similar studies have been started in correlating radio and EUV and x-ray bursts.

Although the spectral correlation of solar microwave radiation has been effective, techniques are being investigated to refine the distinctions among types of solar flares. Dr. D. Guidice at the Sagamore Hill Facility will study the polarization characteristics of solar radiation between 2 and 5 GHz, a major new class of investigation for U.S. solar scientists, although pioneer work has been done in Japan.

In contrast to analysis of solar activity, another approach is to study a measured parameter of the ionosphere such as the total electron content. The observation of the Faraday rotation of the polarization of an electromagnetic wave from a satellite is a technique to measure total electron content, which is useful for measurement of propagation delays in the ionosphere. AWS and AFSC (SAMSO) have both expressed interest in this aspect of the problem. However, using total electron content as a descriptive parameter of the ionosphere and the broad area mapping of it to detect perturbations of the ionosphere are as yet untried. A current analytical effort is the formulation of a global model of the total electron content.

Amplitude scintillation has long been under investigation by the Ionospheric Physics Laboratory. Variations in the received amplitude and phase of a signal that has passed through the ionosphere are tabulated so that the movement of disturbances can be observed or the local state of the ionosphere can be described. One attractive feature of a new phase-measuring interferometer is that distant ionospheric variations can be deduced by looking at satellite beacons low on the horizon; another feature is the simplicity of the equipment. Irregularity studies could therefore play an important role in remote measurements of the ionosphere where gross statements about the stability of the ionosphere are needed.

High latitudes pose many interesting ionospheric problems such as auroral phenomena. A broad research program using ground-based measurements, rockets, and a specially instrumented NKC-135 has been underway at AFCRL for several years. Definition of the auroral oval, geographical extent of both visual and subvisual auroral displays, and electron energy space distributions are under study to provide a foundation for AWS forecasting of auroral phenomena which affect Air Force activities. For example, recent results have shown that some of the D and E layer phenomena can best be ordered and related to the subvisual continuous airglow and corresponding levels of particle flux, rather than to the visual discrete aurora. Further efforts with the Airborne Ionospheric Laboratory may provide specifications which lead to routine monitoring of important ionospheric phenomena in the Arctic through combining real-time data from a few suitably located ground stations and models of the Arctic ionosphere presently being developed from earlier data.

Summary

These changes of the basic research program brought the program into closer alignment with the AWS operational needs. Much research continued with somewhat modified objectives. Some research must become more "applied." As the needs of AWS are satisfied, the program will probably shift back toward more fundamental research, with consultation being the key interaction with AWS. However, orientation of the scientists to AWS problems will serve in the future to couple the scientific results of the laboratory to the operational needs of AWS.

Contact: Col R. B. Kalisch
Telephone Extension 2791

SOURCES AND LOSS MECHANISMS OF RADIATION BELT PROTONS

Space Physics Laboratory, AFCRL

The source of high energy protons in the earth's radiation belts has puzzled geophysicists ever since these protons were first observed in 1959. Equally puzzling is the fact that, once captured by the magnetic field, the protons have few avenues of escape. Yet escapes are made and the radiation belts maintain reasonable equilibrium.

Now Mr. Robert C. Filz of AFCRL and Dr. R. S. White at the University of California, Riverside, have substantially laid both issues to rest. Their theoretical explanation is in excellent agreement with ground and satellite observations over the past 10 years.

Many early investigators assumed that radiation belt protons originated from the sun. But the basic theoretical question – namely, how could the protons penetrate the earth's magnetic shield – would not go away. Therefore other possible sources were considered, one of which was cosmic rays.

Cosmic ray contributions to the radiation belts are indirect. Protons are formed by a process known as cosmic ray albedo neutron decay injection. The heavy, high energy cosmic ray particles penetrate the earth's magnetic shield and collide with oxygen or nitrogen molecules. In the reaction, neutrons are kicked free. A free neutron has a half life of about 12 minutes; it decays into a proton and an electron plus an antineutrino. These charged particles are then captured by the magnetic field and begin the mirrored back-and-forth oscillation between the north and south conjugate points that is characteristic of particles trapped in the radiation belts.

But cosmic ray injection cannot account for the total flux of high energy protons in the radiation belts. From among the other possible sources suggested over the years by various investigators, Filz and his coworkers considered the process known as solar neutron decay. Solar neutrons are a product of solar flares. Because neutrons have no charge, they readily penetrate the earth's magnetic field. Their 12-minute half life assures that statistically a reasonably large percentage will spontaneously decay during their transit through the earth's magnetic field. The resultant proton and electron are then captured.

Theoretical calculations by Filz and White show that cosmic rays and solar neutrons can account for almost all the high energy protons in the radiation belts, with each source contributing almost equally. For protons at certain energy levels and altitudes, solar neutrons are the major contributors; at other energies and altitudes, cosmic rays are the major sources. For example, more protons with energies greater than 30 MeV above $L = 2.2$ (distance in earth radii at the equator of the undisturbed magnetic field) originate through the solar neutron process than through the cosmic ray process.

The influx of cosmic rays into the earth's atmosphere varies only slightly from year to year. However, the influx of solar neutrons varies with the 11-year solar cycle, increasing greatly during the active solar period. Thus, the density of protons in the radiation belts should increase during the active solar period. Surprisingly, the reverse is true. Why?

The reason is atmospheric density. Atmospheric density at altitudes from 100 to 1000 km increases during the active solar period. The study shows that the depletion of high energy protons from the radiation belts is due

Mr. Robert Filz examines discs of photographic emulsions set into plates carried on satellites. Photographic emulsion is used to detect the flux and energies of charged particles in the radiation belts. When these particles penetrate the emulsion, their ionizing radiation creates tracks which clearly delineate the particle path and energy after the emulsion is developed.

predominantly to the interaction of the protons with atmospheric molecules. Thus, if the atmospheric density is known, loss rates can be calculated with great precision.

Such calculations of variations in proton fluxes in the radiation belt were made for the period 1961 to 1970. Calculated variations were in close agreement with observational data. Taking protons of 55 MeV energy at $L = 1.4$ at a height of 350 km as an example, it appeared that the flux during the quiet solar period of 1964 was almost three times that of the flux during the active period of 1969. This variation ratio was shown to exist also for protons at other energies and at other altitudes.

This definitive analysis of radiation belt protons to date points up how far our knowledge has advanced since 1962. That was the year of the Starfish nuclear burst in the atmosphere that produced a sudden and surprising five-fold increase in radiation belt protons at low altitudes. No one at that time foresaw the magnitude of the effect and no one could accurately predict the persistence of the enhancement. As it turned out, the decay was fairly rapid. Within a year, the flux was near normal levels and by 1964 there was no measurable residue. As the results of studies such as that described here, predictions of loss rates can now be made with confidence approaching certainty.

Contact: Mr. R. C. Filz
Telephone Extension 3240

Mr. Robert C. Filz has been a physicist in the Cosmic Radiation Branch of AFCRL's Space Physics Laboratory since 1961. He is currently determining the source and loss processes of inner zone trapped protons, using nuclear emulsions recovered from Air Force satellites. He is also studying the hydrogen isotopic abundance to determine the effects of solar cycle changes in the upper atmosphere. He is planning further experiments in the earth's corpuscular radiation environment, using photographic methods.

Mr. Filz is a member of Sigma Xi, the American Physical Society, and the American Geophysical Union. He regularly publishes the results of his work in collaboration with other scientists and has earned an international reputation.

HAVEN HOP: A CONCENTRATED LOOK AT CAT

Meteorology Laboratory, AFCRL

The most intensive CAT (Clear Air Turbulence) observation program carried out to date took place during the six-week period, January 12 to February 21, 1970, when AFCRL was joined by the Air Weather Service, FAA, NASA, Army, and the National Research Council of Canada in a cooperative program to observe the origins, movements, and severity of CAT. The atmosphere between 10,000 and 45,000 feet was monitored whenever CAT was predicted or found to have occurred. Activities centered at Wallops Island, Virginia.

The purpose of the program (with the code name, HAVEN HOP) was to define techniques leading to CAT forecasting and to better methods of CAT detection. Ground-based radars, instrumented aircraft, and upper air rawinsonde soundings served as the basic data gatherers. HAVEN HOP activities were coordinated by Mr. Peter Giorgio of AFCRL.

CAT has proved to be one of the more difficult meteorological phenomena to predict. Although researchers have found many promising detection schemes based on known CAT correlations (changes in refractive index, temperature variations, ozone concentrations), none has made the transition from technical feasibility to operational use.

The HAVEN HOP program was a concentrated extension of programs carried out by AFCRL meteorologists at Wallops Island over the past four years. With the high resolution radars (3.2, 10.7, and 71.5 cm) at Wallops Island, AFCRL meteorologists have detected even light CAT up to about 28,000 feet with high reliability. Above that altitude, detection reliability falls off rapidly. Nevertheless, AFCRL meteorologists believe that, with more sensitive radar detection, comparable reliability to altitudes above 40,000 feet is within easy grasp. If successful, the program could lead to the installation of a chain of CAT detection radars along the nation's commercial airways. The problem then would become one of economic feasibility.

The insidious nature of CAT makes it difficult for one pilot to warn another in the area of its specific location, chiefly because of the limited vertical extent of a particular patch and its limited persistence. It may have a vertical extent ranging from only about 30 feet to occasionally more than 5,000 feet. It persists for a relatively short time at any one place—a time measured in terms of 10-minute periods.

As a result of AFCRL research starting with the use of an instrumented U-2 in the early 60's, a fair understanding has been gained of the causal chain of relationships that gives rise to CAT. The first requirement is a well defined and stable wind stream in the atmosphere. The jet stream is the best example of this. (When there is a marked change in velocity or direction of winds within a limited volume of space, as there would be at the boundaries of the jet stream and surrounding air, a condition known as wind shear exists; wind shears of interest to CAT watchers are vertical wind shears.) The critical wind shears are most frequent at the tropopause, the altitude (generally between 35,000 and 40,000 feet in mid-latitudes) at which atmospheric temperatures no longer decrease with altitude. CAT is also found in conjunction with temperature inversions at lower altitudes. These inversion layers may have a broad geographical extent,

stretching across half the country. Once a horizontal wind flow has attained full development, some irregularity in the flow must occur. The flow can become wavelike, with the breakup of the even flow giving rise to turbulence. In the process, different air layers are mixed, producing changes in the index of refraction of air in a limited region. Radars can detect these changes in refractive index and will interpret such changes as indicators of the presence of CAT.

In addition to the continuous observations made by Wallops Island radars during the HAVEN HOP program, the program included a large number of instrumented RB-57 aircraft flights into regions of CAT to check radar observations against severities measured by the aircraft. T-33 aircraft made similar penetrations and also carried instruments to measure temperature, pressure, dew points, wind, and wind gusts. During CAT observation periods, rawinsonde balloons were launched at two-hour intervals throughout the six-week observational period from eight stations of a 12-site network, and at six-hour intervals from the other four stations. This rawinsonde network extended from Delaware on the north to Cape Hatteras, North Carolina, on the south, and from the Atlantic coast westward to Huntington, West Virginia.

Excellent data were obtained. Results will be published in the coming months.

Contact: Mr. Peter A. Giorgio
Telephone Extension 2473

As assistant to the Chief of the Meteorology Research Laboratory, AFCRL, Mr. Peter A. Giorgio is responsible for its administrative and management aspects.

In 1937 he received his B. A. from St. John's University, Brooklyn, N. Y., and in September 1943 he received a certificate in Meteorology from MIT.

He has had extensive experience as a weather officer, as a physical oceanographer (U. S. Navy Hydrographic Office) and as a meteorologist.

Mr. Giorgio is a member of the American Meteorological Society. He has contributed four sections to one published book and two chapters to a Geophysical Research Paper

Project Haven Hop, one of the most extensive programs undertaken to date to measure the sources and behavior of CAT, was directed by Peter Giorgio (left). Others participating in the program were Samuel Penn (center) and Capt. Gary Thompson.

ARGON MOLECULE ABSORPTION: A DEFINITIVE STUDY

Aeronomy Laboratory, AFCRL

Recently submitted for publication by Dr. Y. Tanaka and Mr. K. Yoshino of AFCRL is the paper "Absorption Spectrum of the Argon Molecule in the Vacuum-UV Region." This paper is the definitive study to date of the argon molecule spectrum and promises to become an important part of the standard reference literature. During the past two decades the community of spectroscopists has come to expect such thorough analytical and experimental studies from Dr. Tanaka and his UV spectroscopic group at AFCRL.

The attention of those outside the community, however, is unlikely to be captured. The reason is that a building block, however finely chiseled and essential to a structure, seldom has intrinsic interest. Although purely spectroscopic studies give insight into the fundamental energy mechanisms of particular molecules, such studies are often a means to an end rather than the end itself. In this sense, the Tanaka-Yoshino argon study represents a refinement to a basic scientific tool, a more detailed calibration of a fundamental and universal scale.

UV spectroscopy is a major branch of spectroscopy which is unrivaled in importance among scientific measurement techniques. The UV spectrum for any particular gas element consists of a near-infinite number of lines. New spectrographs of higher resolution permit new lines and systems of lines for each element or

molecule to be identified. The spectroscopist has "discovered" a new line when he has associated it with a specific atom or molecule and has explained the transitions in energy levels involved in its creation. But the energy mechanisms that produce the full spectrum of a particular gas are so numerous and complex that they elude full comprehension. In general, however, the UV absorption lines involve the electronic transitions in an atom or molecule from a ground state to one of a number of possible higher energy states. For the emission lines, the mechanism is reversed: the molecule falls to a lower energy level and emits radiation. Transition from a higher energy state to a lower one produces bands of light of discrete wavelengths characteristic of particular atoms or molecules. Assuming that no magnetic or electrical fields are present to split or displace the lines, the lines for a particular molecule or atom always fall at precise and characteristic locations along the spectrum.

The spectral region encompassed in the Tanaka-Yoshino paper on argon absorption spectra covers the UV region of 780 to 1080 angstroms. Within this region, the AFCRL spectroscopists observed nine discrete band systems for the argon molecule, Ar_2, some of which encompass 30 or more individual lines. They analyzed the particular electronic transitions from the ground state that resulted in each of these band systems, and discussed the energy mechanisms for each. This energy is not completely the result of electronic excitation. For example, six vibration levels for argon molecules in the ground state were identified, as well as lines produced by the splitting of the diatomic argon molecule into separate atoms. (Molecular vibrations are ordinarily associated with infrared spectroscopy, but can also have a role in UV absorption and emission.)

Measurements of the argon molecule were made at the partial pressure of less than 0.01 torr with the absorption cell cooled with liquid nitrogen. For analytical purposes, measurements were also made over a range of temperatures and pressures, using a 6.65 meter normal-incidence vacuum spectrograph.

Dr. Y. Tanaka (right) and K. Yoshino are shown at one of AFCRL's spectrographs used to investigate the excitation of various gases.

A similar analysis of the xenon molecule was previously published by Dr. Tanaka. He has made studies of most of the rare gases and the gas constituents of the earth's atmosphere. The atmospheric physicist, among others, is a user of the studies described here. These studies provide him with the means for deriving the relative concentration of atmospheric species and for interpreting the dynamic chemistry of the atmosphere sustained by solar energy.

Contact: Dr. Y. Tanaka
Telephone Extension 3040

Mr. Kouichi Yoshino is a research physicist at the Spectroscopic Studies Branch, Aeronomy Laboratory, AFCRL, where he is currently conducting research in the field of vacuum ultraviolet spectroscopy of atmospheric gas molecules.

He received a B.A. in 1953 and an M.S. degree in Physics in 1955, both from the Tokyo University of Education.

Mr. Yoshino is a member of the Physical Society and the Spectroscopical Society of Japan. He is the author of several articles published in Japanese scientific journals.

Dr. Yoshio Tanaka is a research physicist at the Spectroscopic Studies Branch of the Aeronomy Laboratory, AFCRL. At present he is engaged in the vacuum spectroscopic study of the atoms and molecules constituting the atmosphere. He came to AFCRL in June 1952.

He received his M.S. in 1935 and his Ph.D. in Physics in 1944, both from Tokyo University of Literature and Science, and later taught at Tokyo University where he attained the rank of full professor.

He is a member of the American Physical Society and RESA, and a fellow of the Optical Society of America. He has published several papers on the molecular spectra of various chemicals.

SEPARATION OF CONTRIBUTIONS TO WEIGHT CHANGE OF VOLATILE AND NON-VOLATILE PRODUCTS DURING HIGH TEMPERATURE OXIDATION MEASUREMENTS

W. C. Tripp, Systems and Research Laboratories, Inc. Dayton, Ohio and

Dr. H.C. Graham, Metallurgy and Ceramics Research Laboratory, ARL

Recently scientists working at the Metallurgy and Ceramics Research Laboratory of the Aerospace Research Laboratories in cooperation with the Systems Research Laboratories, Inc. have developed thermogravimetric techniques for measuring the oxidation kinetics of materials that form volatile oxides which are condensible at temperatures below the reaction temperature. These techniques have been utilized in a study of the oxidation of zirconium diboride, ZrB_2. When a boride such as ZrB_2 oxidizes, one product formed is boron oxide B_2O_3 which is a liquid above 450°C and which has an appreciable vapor pressure above 1000°C. In conventional weighing techniques, any volatile oxide formed is recorded as a weight loss; if more than one oxide is formed during oxidation, it is difficult to determine the relative amounts of the various oxides or to follow the kinetics of oxide formation.

Three relatively simple techniques, requiring only a balance of large capacity and adequate sensitivity, have been used to separate the oxidation processes occurring in the oxidation of ZrB_2. These techniques are:

1. Sample weight change: conventional weight change measurements where only the weight of the oxidation products remaining on the sample are recorded.

2. Oxygen consumption: the weight of the sample plus the weight of any volatile oxide that is condensible within the temperature range of the system is measured.

3. Vaporization: only the weight of the condensible oxides is measured.

The measurement of sample weight change is simply the conventional technique of recording weight as a function of time at set conditions of temperature and oxygen pressure. The recorded weight gains represent a gain in weight from the oxygen used to form ZrO_2 and B_2O_3 minus a weight loss due to the vaporization of an unknown quantity of B_2O_3. Since the amount of B_2O_3 vaporizing is unknown, this method of weighing is not an accurate measure of the oxidation kinetics.

The measurement of oxygen consumption (the total quantity of oxygen forming ZrO_2 and B_2O_3) was accomplished with the arrangement shown in figure 1A. An inverted crucible 100 mm long is suspended from the balance, with the specimen hanging inside. Since the top end of the crucible is considerably cooler than the sample, any B_2O_3 vaporizing will condense here. Since the entire crucible plus the sample are being weighed, the total oxygen used to form both oxides is being measured.

A slight modification of this technique, as shown in figure 1B, permits measuring only the amount of B_2O_3 vaporizing. The sample is inside the crucible but not connected to the balance, so that only condensation on the cool end of the crucible is weighed.

Using these techniques in the investigation of the oxidation of ZrB_2, the data shown in figure 2 were obtained. The curve labeled "sample weight" represents the net weight gain observed by conventional weighing methods. The "oxygen consumption" curve represents the total oxygen consumed, because all of the oxidation products are collected and weighed. The "vaporization" curve, which is a measure of the B_2O_3 vaporized, was obtained by weighing only the oxide that collected at the cool end of the crucible.

The utilization of these weighing techniques has resulted in a better understanding of the processes involved in the oxidation of ZrB_2. In the current continuation of this work, these techniques are being applied to boride materials with additives such as silicon carbide, SiC, which will form a second condensible oxide, silicon dioxide, SiO_2.

Contact: Dr. H. C. Graham
Telephone Extension 54387.

Dr. Henry B. Graham has been a research physicist in ARL's Metallurgy and Ceramics Research Laboratory since September 1960. In his study of the defect structures of various metal oxides, he has set up several unique measurement systems to measure various electrical properties of the oxides as a function of temperature, frequency, and oxygen partial pressure.

Dr. Graham's degrees were all earned in Ceramic Engineering: a B.S. in 1956 and an M.S. in 1958 from Alfred University, Alfred, N. Y., and a Ph.D. in 1965 from the Ohio State University. He has presented papers on his research to seminar-type meetings.

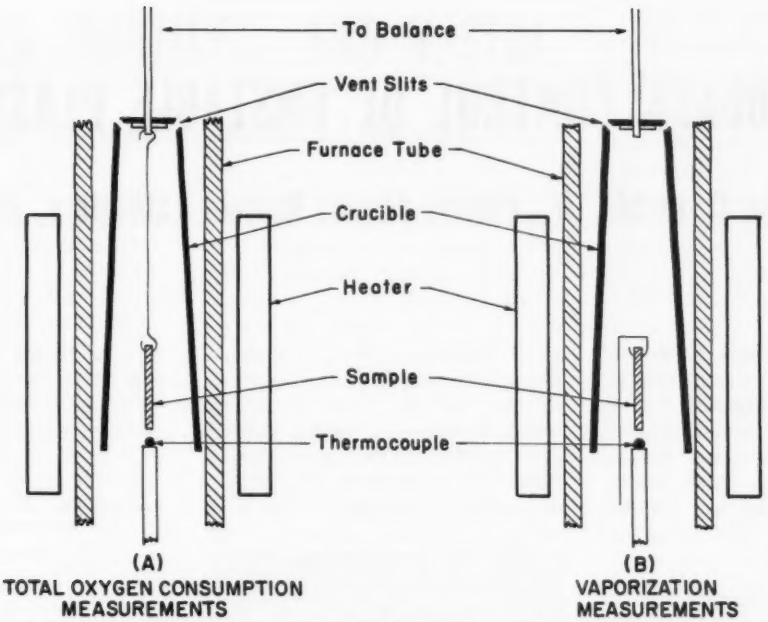

Figure 1. Sample suspension for measuring (A) total oxygen consumption and (B) vaporization rates of a condensible oxide.

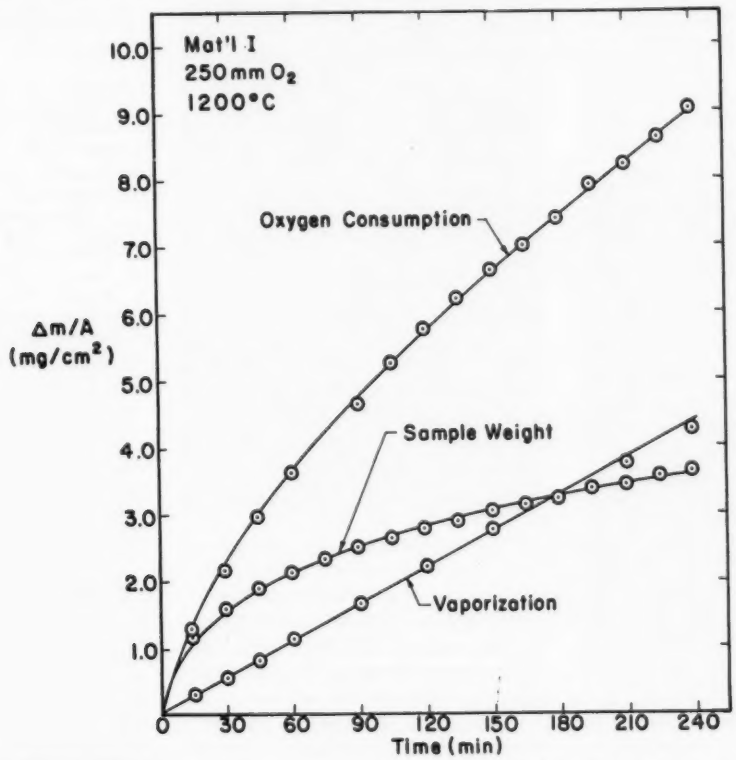

Figure 2. Three types of measurements of the oxidation rate of ZrB_2 at 1200° C and 250 torr O_2.

FEEDBACK CONTROL OF UNSTABLE PLASMAS

John C. Corbin, Jr., Plasma Physics Reseach Laboratory, ARL

The use of feedback control to reduce or eliminate instabilities in plasmas was first suggested in the Russian literature in 1962. Subsequent papers by a number of authors (1964-1967) examined the feasibility of continuum feedback and pointed out practical means of achieving a successful control system.

The first successful application of feedback control to an unstable plasma was not reported until 1968 when V. V. Arsenin et al (1) were able to suppress the flute instability on the OGRA II mirror machine. Since that time, relatively simple external feedback control schemes have been applied to plasmas in a growing number of experiments, with varying degrees of success. Parker and Thomassen at M.I.T. stabilized low-frequency electrostatic waves in a weakly ionized hot-cathode reflex discharge by feeding an amplified and phase-shifted probe signal to a pair of plates at the discharge walls (2). Keen and Aldridge at Culham Laboratory, England, used a similar scheme in a hollow-cathode arc discharge running in argon to stabilize a radial electric field-driven "drift-type" instability (3). Simonen, Chu, and Hendel at Princeton used one sensor and one suppressor probe in a simple feedback system in which phase shift and gain were controlled to reduce the amplitude of collisional drift waves and to improve plasma confinement in a thermally ionized potassium magnetoplasma (4).

The Plasma Physics Research Laboratory at ARL is constructing and performing exploratory experiments on a small mirror machine (ELMAX) which will have controllable features for the stabilization and confinement of a moderately high temperature plasma. Controlled plasma injection will be used to tailor the plasma density to achieve a particle distribution which closely approaches a Maxwellian distribution. Since this is an equilibrium distribution, most of the troublesome instabilities which are driven by a non-Maxwellian distribution should not appear. Provisions have been made to apply and control large external electric fields to assist in achieving the desired density distribution. Relatively fast plasma rotation will be set up in the $\bar{E} \times \bar{B}$ direction, with a possible reduction of the internal magnetic field. In such a rotating plasma, so-called microscale instability loss mechanisms will probably be suppressed, leaving azimuthal drift and flute type instabilities which can be treated by external active dynamic stabilization techniques. Accordingly, the design of the device provides external feedback loops distributed azimuthally around the plasma.

To date, few studies have been made of practical design problems associated with feedback control of plasma instabilities. Problems arise from the necessity of constructing the feedback system from a finite number of feedback loops which influence a finite volume of the plasma in a non-uniform manner. The effects of electrode number, size, shape, and position with respect to various plasma configurations will be examined to determine the phase shifts, time lags, and mode number responses which can limit the achievable stabilization.

Because of the accelerating interest in feedback control and dynamic stabilization of plasmas, the first "International Symposium on Feedback Control and Dynamic Stabilization of Plasma Instabilities" will be held at Princeton University in June 1970. Results from the ELMAX experiment will probably be reported at that time.

Contact: Mr. John C. Corbin, Jr.
Telephone Extension 52923

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(2) Parker, R. R. and K. I. Thomassen, "Feedback Stabilization of a Drift-Type Instability," *Phys. Rev. Letters*, 22 (12 June 1969), 1171.

(3) Keen, B. E. and R. V. Aldridge, "Suppression of a 'Drift-Type' Instability in a Magnetoplasma by a Feedback Technique," *Phys. Rev. Letters*, 22 (23 June 1969), 1358.

(4) Simonen, T. C., T. K. Chu and H. W. Hendel, "Feedback Control of Collisional Drift Waves by Modulated Parallel-Electron-Current Sink-Experiment and Interpretation," *Phys. Rev. Letters*, 23 (15 Sept 1969), 568.

Mr. John C. Corbin, Jr., has been with ARL since 1959. He is now the Deputy Director of the Plasma Physics Research Laboratory where he assists in the management and technical direction of studies to determine plasma characteristics essential to new Air Force applications.

Mr. Corbin received his bachelor's degree in Electrical Engineering from Cornell University in 1950 and became a registered professional engineer in Ohio in 1955. He earned his M.S. in Electrical Engineering in 1963 from the Ohio State Graduate Center where he studied on a part-time basis while working for the Wright Air Development Center and ARL. In May 1968 he passed the General Examinations for a Ph.D. degree in Electrical Engineering at the Ohio State University. Mr. Corbin is a member of the IEEE's Group on Engineering Management.

CIGARETTES, VORTICES, AND V/STOL

Dr. Brian Quinn, Energetics Research Laboratory, ARL

The twists and curls of cigarette smoke rising in a slight draft reveal a complex aerodynamic interaction. The smoke in the photograph shown in figure 1 appears to be laminar close to the burning ember, although the waviness implies an unstable condition. As the smoke progresses downstream, the instability increases, eventually attaining a structure which is reminiscent of ring vortices translating at nearly constant speed and spacing. However, closer scrutiny shows that the ring-like vortices are incomplete. Instead of closing, their lower portions reach far downstream and entwine to form the core of a vortex which is aligned with the general direction of the flow. If the observer were positioned downstream, with the smoke blowing into his face, he would notice two streamwise vortices, each rotating in an opposite direction.

The flow structure seen in the photograph in figure 2 is similar. We see the laminar region with the waviness characteristic of instability, the growth of the waves into ring-like vortices of nearly equal spacing, and then the development of two counter-rotating streamwise vortices.

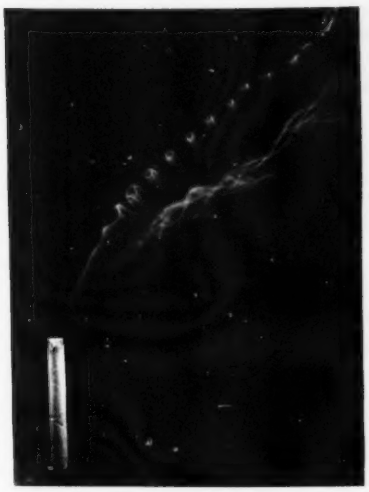

Figure 1. Thermal jet is a cross flow.

Almost as striking as the similarity in the two photographs are the differences in experimental conditions. The first photograph resulted from the interaction of a very slight breeze with a weak thermal jet being buoyed aloft by its reduced density. In the second photograph, a stream of water had encountered a cross-flowing liquid jet of like density. Instead of being driven by differences in thermal energy, this interaction process was derived from differences in components of momentum.

Figure 2. Low Reynold's number liquid jet in a water stream.

While acknowledging the aesthetic properties of flow photographs, an unknowing critic might hasten to disclaim the relevance of the subject matter. He would be soundly mistaken. As it happens, the interaction of a jet with a cross-stream relates to two of our nation's more pressing social problems—air pollution and transportation.

The photograph in figure 3 shows the development of industrial chimney effluents upon ejection into the prevailing wind. The initially turbulent smoke jet forms the two characteristic streamwise vortices and in other respects preserves the pattern established by its laminar cousins, five or six orders of magnitude removed in Reynolds number. This pattern is repeated by the energized efflux of such V/STOL aircraft propulsion systems as the helicopter rotor, tilt-prop, and fan-in-wing concepts. While the conservationist is concerned with rates of dilution and sedimentation, the aerodynamicist must attempt to relate the pressure, downwash, and circulation around the aircraft to the vortices induced by the interaction of the high energy jet with the oncoming free stream. Both specialists are hampered in attaining their respective objectives by the lack of a unified theoretical description of the flow interaction process. It is in such a situation that the true value becomes evident of photographs similar to those appearing in this article, for in addition to the quantative data imprinted on their emulsions, they serve as a source of ideas which will eventually lead to the elusive mathematical description.

Figure 3. Counter-rotating vortices produced by industrial effluents in a breeze.

Dr. Brian Quinn, aerospace engineer at the Energetics Research Laboratory at ARL since September 1967, received his Ph.D. from the University of Paris in 1964.

WEATHER AND VARIATIONS IN SOLAR ENERGY

Meteorology Laboratory, AFCRL

Meteorological literature abounds with studies showing an association between variable solar energy emissions and the subsequent behavior of the weather. Still, there is widespread doubt in the meteorological community as to the reality of this association. One reason for this skepticism concerns the physics of the situation. Compared with the massive energy variations of the normal tropospheric processes that generate and sustain the earth's weather, solar energy variations are so small that it is difficult to design experiments and make measurements that conclusively establish cause-and-effect relationships.

However, one link in causal relationship has been fairly well established. Rather convincing evidence has been accrued showing the connection between long-term solar energy variations associated with the sunspot cycle and the temperature of the atmosphere at altitudes above about 60 km. If it can be shown that these high-level temperature changes can be propagated downward into the troposphere and then amplified by existing atmospheric potential, skepticism regarding solar-weather relationships will diminish.

Drs. Louis Berkofsky and Ralph Shapiro of AFCRL have investigated this matter, using a numerical model. With numerical modeling techniques, the total atmosphere can be simulated and various energy mechanisms can be analyzed under controlled conditions. The Berkofsky-Shapiro numerical model, which was developed almost 10 years ago, has since undergone many refinements. The present version assumes that the distribution of atmospheric parameters with height is known. Within the framework of this limitation, the AFCRL numerical model clearly indicates that temperature variations in the upper atmosphere are propagated downward to the troposphere and then amplified to produce changes in the earth's weather.

The numerical modeling process starts with some initial atmospheric state. To simulate the atmosphere, the computer must integrate through many time-steps (30 minutes in this case) a multitude of dynamically interrelating factors. By choosing the initial atmospheric state from an actual date, the weather patterns evolved by the computer can be checked against the patterns that actually occurred. For their study, the two AFCRL investigators selected the atmospheric states over the Northern Hemisphere for January 2, 1964, and April 18, 1965. On these dates, a burst of high-energy solar particles had produced moderate-to-large geomagnetic disturbances and associated auroral activity.

As early as 1956, Dr. Shapiro suggested that such disturbances increase the temperature of the upper air. Small, but significant, adjustments of the surface pressure in the middle latitudes following large increases in geomagnetic activity seemed to be connected with this activity. Shapiro noted a longer lifetime, or persistence, of a particular pressure pattern. This persistence effect was a delayed one, occurring about a week after a geomagnetic disturbance. However, two and a half weeks after a geomagnetic disturbance, persistence decreased below average. From the standpoint of the earth's weather, increased persistence is directly correlated with the movement of air masses—with increased zonal flow. Nevertheless, the Shapiro observations were inconclusive because of possible sampling error or experimental bias.

The question posed in the AFCRL computer modeling study was this: Given an initial atmospheric state, what happens when the upper atmosphere is heated, and what happens to this same atmospheric state when no heat is added? In the two cases analyzed—the states on January 2, 1964, and April 18, 1965—the computer forecasts, produced when heat was added, more closely matched the actually observed conditions than those of the same initial states when no heat was added. If the numerical model did reasonably approximate the actual atmosphere, the indication is that the heating caused by geomagnetic disturbances may indeed affect the earth's weather.

If variations in solar emissions can ultimately be shown to be a triggering mechanism of the earth's weather, thus tightly correlating a given cause with a given effect, then a big step will have been taken toward long-range weather prediction.

Contact: Dr. L. Berkofsky
Telephone Extension 2972

Dr. Louis Berkofsky joined AFCRL's Meteorology Laboratory as a research physicist in the Dynamics Branch in 1948 and is now Chief of the Branch. Since 1940 he has been engaged first in work on objective forecasting techniques and then in "numerical weather prediction." Present problems include a theoretical solar-weather model, hurricane prediction, the quasi-biennial oscillation, and a numerical boundary layer model.

In 1946 Dr. Berkofsky received a B.A. in Mathematics from Brooklyn College and in 1948 he received an M.S. in Meteorology from New York University. His Ph.D. in Meteorology was earned at the Massachusetts Institute of Technology in 1958. Since 1963 Dr. Berkofsky, a member of Sigma Xi and the American Meteorological Society, has published many articles on his work.

MODEL OF VENUS ATMOSPHERE

Microwave Physics Laboratory, AFCRL

On Venus we would find ourselves in an intense and perpetual dust storm, the wind sweeping across the arid surface of the planet and picking up dust particles eroded to fine aerosols. These particles are carried to great heights (up to 60 km) by the strong convection currents created by the 820°K daytime temperatures. If we were to remain on the planet through one rotation period of 243 days, we would find the night temperatures to be about 620°K. During the night, we find little change in concentration of dust particles in the surface atmosphere, even though strong convection has ceased and dust concentrations at higher altitudes have greatly decreased.

All of these inferences, and others, can be drawn from a model of the Venus atmosphere developed by Paul M. Kalaghan of AFCRL. The model was derived from radio observations of both the illuminated and unilluminated hemispheres of Venus at 3.15 cm, 8.6mm, and 3.4mm. The 8.6 mm observations were made at AFCRL's Prospect Hill Radio Observatory in Waltham, Mass.; the other observations were made elsewhere by other investigators. The model indicates that a much greater difference exists between the daytime and nighttime temperatures of Venus than previously believed, and that the concentration of dust particles in its atmosphere may be much higher than others have suggested.

The Kalaghan model is based on the study of the spectral characteristics of the Venus radio brightness temperatures. The model starts with a consideration of the plots of daytime and nighttime temperatures as a function of wavelength. Even before making the plots, a knowledgeable investigator would probably be able to guess their nature. He would describe two descending parallel lines—the upper one representing the higher daytime temperatures as a function of wavelength; the lower one, the nighttime temperatures. He would guess that the highest temperatures would be registered at the longer wavelengths because only the longer wavelengths from the hot Venus surface and lower atmosphere could penetrate the Venus atmosphere. The millimeter wavelengths emanate from less dense and cooler regions of the upper atmosphere.

The guess would be close, with a minor, but highly significant, difference: the two temperature-wavelength lines are not exactly parallel. Because the nighttime temperatures plot is flatter, the lines must cross at some point. In the Kalaghan plot, they cross at about 4 mm, signifying that at 3.4 mm the temperature measured for the unilluminated hemisphere is actually higher than that for the illuminated side. This fact suggested to Kalaghan that quite different physical conditions must exist on the day and the night faces of the planet. The problem then is to define the kinds of atmospheric environment that must exist to account for the radio observations.

Formulation of the model to account for these differences required much IBM 7090/7044 assistance in dealing with upward and downward heat fluxes and in making the tricky calculations of optical depth, a measure of the penetration of radio waves through the Venus atmosphere. The optical depth of CO_2, its predominant atmospheric constituent, varies greatly with temperature. But optical depth is primarily affected by the dense atmospheric dust of Venus. Therefore, if the dust carried to high levels during the Venus day descends to lower levels at night, the shorter wavelengths emanating from the warmer lower levels could then penetrate the atmosphere. This theory accounts for the higher nighttime temperature measurements at 3.4 mm.

The Venus atmosphere model also permits calculations for lapse rates, or the rate at which atmospheric temperatures decreased with altitude. In this connection, the Kalaghan model establishes the tropopause (where atmospheric temperatures stop decreasing with altitude and begin to rise again) at 60 km. This level is in remarkably close agreement with Mariner-5 data, as are other temperature data derived from the Kalaghan model.

Mariner-5 temperature data are consistently higher than the temperature data recorded by the Soviet Venera-4 probe during its descent through the Venus atmosphere. Kalaghan suggests that temperatures derived from his model, and those measured by Mariner-5 and Venera-4, would all be in good agreement if we assumed that the reported altitude of Venera-4 was in error by 20 km. Adjusting altitudes upward by 20 km would make the temperature data reported at various strata by the Venera-4 conform to Mariner-5 measurements.

Contact: Mr. P. M. Kalaghan
Telephone (commercial)
893-5353

Mr. Paul M. Kalaghan has been a research physicist in the Millimeter Wave Branch of AFCRL's Microwave Physics Laboratory since February 1966. He is presently conducting solar observations to obtain information on millimeter-wave disturbances on the sun and their association with optical flares and solar proton shower events.

Mr. Kalaghan received his B.A. in Physics in June 1956 from Harvard College and his M.S. in Applied Physics the following year from Harvard University.

Earlier investigations conducted by Mr. Kalaghan dealt with (1) various lunar surface models and the explanation of their millimeter-wave radiation characteristics, (2) solar flux observations of variations in daily atmospheric attenuation, and (3) measurement of the quiet and slowly varying components of the solar flux at 8.6 mm and 4.3 mm.

Mr. Kalaghan is a member of the American Association for the Advancement of Science and has published numerous articles on his work.

READERS INTERCHANGE

It is hoped that the Readers Interchange, under the columns headed "Research Needs" and "Speculative Ideas," will encourage reader participation in suggesting further basic research for the scientist that will lead to new product development for the engineer. As a further source of reader participation, the answers to question 2 of the tear-out page, "Comments to the Editor," in which applications are suggested for the research described in any article of this issue, may be published in the Readers Interchange of a subsequent issue (with the permission of the reader).

On the other hand, the column headed "Research Advances" which contains materials furnished by our own research laboratories (AFCRL, ARL, AFOSR, FJSRL, and EOAR), and the items in the column headed "Invention Disclosures" which are selected from current invention disclosures, originally submitted for possible patent applications, but now released from such action,* may suggest further research for our readers.

Reports of actions stimulated by the Readers Interchange or suggestions for its improvement are welcome.

Director of Laboratories, AFSC (DL)
Technical Information Office (DLLT)
Andrews Air Force Base
Washington, D. C. 20331

**For a more detailed discussion, see "Project: Use It" by Lt Col Ludwig Lippert, Staff Judge Advocate, in the OAR Research Review, Vol. IX, No. 3, May-June 1970.*

Research Advances

Piezojunction Sensor/Transducers

Development: From the current understanding of phenomena associated with piezojunctions under stress, a new family of sensors and transducers can be developed with the characteristics of low cost, low-power requirement, small size, and large dynamic range.

Application: The trimesa piezojunction and semiconductor silicon needle in support of specific air data and guidance and control requirements in airborne equipment and in space applications, or to any sensor/transducer problem.

Sponsor and Project Identification:

AFOSR (SREE) Project No. 9768 Coupling Report No. AFOSR 70-1
Project Monitor: Captain J. F. Kantak
Telephone: Area Code 202 694-5518
AUTOVON 22-45518

Metal Chelates for Research and Ultratrace Analysis

Development: Separation and ultratrace analysis of metals using metal chelate compounds and vapor phase techniques such as gas chromatography. This analysis method is so sensitive that quantities smaller than a trillionth of a gram can be detected in some instances.

Applications: (1) Trace analysis by AMRL of beryllium in biological specimens. (2) AFFDL is working on a concept for generating oxygen in-flight for crew breathing.

Sponsor and Project Identification:

ARL (ARC) Project No. 7023 Coupling Report No. ARL 70-7
Project Scientist: Dr. Robert Sievers
Telephone: Area Code 513 255-4612
AUTOVON 78-54612

Research Needs

Solid State Materials

Areas of Need

1. Growth techniques and property analysis of ferroelectric and pyroelectric materials.
2. Epitaxial growth techniques for magnetic materials.
3. Improved silicon material on insulating substrates such as sapphire and spinel.
4. High band-gap, high quantum efficiency electroluminescent materials for light emitter diode displays.
5. High dielectric, low loss materials for microelectric thin film capacitors.

Contact: Mr. James Huckaby, AFAL (AVRO)
Wright-Patterson AFB, Ohio 45433
Telephone: Area Code 513 25-55771

RN-70-2

Special NASA Project

The Aerospace Safety Research and Data Institute at the NASA Lewis Research Center has been directed to conduct additional research on materials compatibility, ignition, and combustion at various G levels, and on the characteristics of supercritical fluids, as recommended by the Apollo 13 Review Board.

Aerial Photography Improvement

Problem: When pictures are taken through an airplane window, the resolution of the picture is degraded by inhomogeneities in the window and in the medium outside because of the mechanical influences of the flight. Turbulent flow, vibration, temperature, and pressure effects produce deterministic and stochastic changes of the optical transfer function from the camera to the object.

Investigation and correction of these changes are needed to obtain improved resolution and accuracy for the pictures.

Areas of Need:

1. A comprehensive analysis and description of the distorting parameters.
2. An investigation of the scaling of the effects with size increase and change of flight conditions.
3. Remedial actions such as correction of the deterministic influences; investigation of best location and shape of the window; and consideration of other procedures and designs for improvement.
4. Design suggestion for an optically perfect but environment-resistant *lightweight* window.

RN-70-4

Contact: A. W. Berg, AFAL (AVRP)
Wright-Patterson AFB, Ohio 45433
Telephone: Area Code 513 25-52033 or -52511

Invention Disclosures

Bionic Fuel Cell

A fuel cell for generating electrical energy to help create self-sustaining atmospheres for humans or animals in closed spaces where partial pressure or concentration gradients of CO_2 are available in excess of the CO_2 gradient of the metabolic process.

The proposed devices could substitute, when operated by pressurized CO_2, for batteries and perhaps small motor generator sets. They may have advantages over current devices in (1) cost of operation, (2) weight, (3) long shelf life, and (4) safety of operation under critical conditions. [Developed by James C. DeHaven, RAND Corporation, under Air Force Contract AF49(638)-700.]

ID-70-7

Variable Altitude Balloon

A balloon which, through its ability to change altitude, establish a new stable floating altitude a multitude of times, and return to a given altitude at will, can provide a versatile platform for instruments to examine the earth, the atmosphere, and space. Consists of a super-pressure balloon with a strong inextensible outer envelope containing an internal bladder of lighter gauge inextensible or extensible material, together with a pump, valve, power source, and timer or telemetry apparatus. [Developed by Stanley M. Greenfield and Milford H. Davis, RAND Corporation, under Air Force Contract AF49(638)-700.]

ID-70-8

Multipurpose Valve

The valve body is made of TEFLON. The upper portion of the valve body is threaded to receive a metal nut which has a tapered thread. Tightening the nut compresses the valve body around the stem to prevent leakage. Although the valve body can be made of various polymers or soft metals, TEFLON is especially preferred due to its chemical inertness and its low coefficient of friction which permits free rotation of the stem. Similarly, a simple nut having a tapered thread is the preferred compression means in view of fabrication costs and the uniformity of forces exerted on the valve body. [Developed by B. K. W. Copeland and E. W. Williams, Atlantic Research Corp., under Air Force Contract AF49(638)-1131/AFOSR (SREP).]

ID-70-9

Contacts: Col Ludwig Lippert, AFSC
Telephone: OX 4-5054

DDC for documentation on the
Air Force grant or contract

Applications Suggested by Readers

Use the improved polarimeter developed at AFCRL by Chester Malik and John A. Klobuchar to investigate the redistribution of F-region electrons during ionospheric storms.

Study of the electron content at spaced locations should aid in explaining radio observations made during ionospheric storms that indicated marked decreases in peak electron density in some geographic regions while the virtual reflection height increased as if the electrons were being transported upward; on the other hand, in some regions the peak density was observed to increase.

John R. Herman
Analytical Systems Corp.
11 Ray Avenue
Burlington, Mass. 01803
Telephone: 617 272-7910

GPO 899-978

Requests for further information from institutions and individuals in the U.S.A. may be either mailed to the addresses below, or telephoned to the individuals named as "Contact" at the end of each article. If no organization follows the name of the contact, assume that it is the same organization given under the title of the article.

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